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Recurriculation of Engineering, Technology, and Technical Education Programmes for the adoption of Industry 5.0

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Abstract

Industry 5.0 is a new emergent industrial revolution that admits and promotes mutual and coordinated interaction of industrial workers' cognitive and creative skills, and artificial intelligence machines' qualities to maximize production in industries. Thus, the advent of Industry 5.0 demands new skills, knowledge, attitude and responsibilities/roles from workers to enable them to fit the positions. Consequently, Industry 5.0 has significant implications for engineering, technology and technical education programs. These programs need to be reshaped for the purpose of producing worthwhile graduates that can easily be absorbed into Industry 5.0. However, this article focuses on the 'recurriculation' of engineering, technology and technical education programs for adopting Industry 5.0. The article is anchored on a literature review. Specifically, the article dwells briefly on the pre-industrial revolution, Industry 1.0, Industry 2.0 and Industry 3.0. The article explicates on Industry 4.0 and Industry 5.0. Similarly, the article identifies problems that emanated during the Industry 4.0 era. It explains the importance of human beings in industries. Also, this article explains the needs for improving the knowledge, skills and attitude of industrial workers during Industry 5.0. Being a program where knowledge, skills and attitude needed in industry 5.0 can be acquired, the article briefly conceptualizes engineering, technology and technical education. Furthermore, the article explains the concept of recurriculation of engineering, technology and technical education programs. Finally, the chapter explains the phases for the recurriculation of engineering, technology and technical education programs.

Keywords

Industry 5.0, Engineering Education, Technology Education, Technical Education, Recurriculation

Introduction

Technology and its development is as old as human beings. Kozí (2015) agreed that human beings were, are and will be the main initiators of any technological innovations and changes that increasingly enter the professional and private lives of adults as well as children. Thus, the source of technological change and its development is responsible for the fulfilment of the needs and wants of individuals and society at large (Graube & Theuerkauf, 2005). This is because human beings, in the process of satisfying basic and essential needs and wants, continue to think and engage in problem-solving activities, hence discovering new technologies which serve as means for the attainment and satisfaction of the needs and wants. The eagerness and zeal to increase human and societal satisfaction of wants and needs that upholds evidence of popular economics theory, “human wants are insatiable” (Bianchi, 2002; Lebergott, 1993; Witt, 2001) has transformed into the continuous development and improvement of technology globally which, by an extension, led to the continuous emergence of industrial revolutions ranging from pre-industrial revolution through Industry 1.0, Industry 2.0, Industry 3.0 and Industry 4.0. Currently, Industry 5.0 is progressing.

By implication, technological and industrial changes will have influence on education. This is because educational institutions such as schools, colleges of technology, polytechnics, and universities train and produce prospective industrial workers (engineers, technologists and technicians) for effective and efficient application of technology for individual, industrial and societal benefit. Every change in the industry will make educational processes and content change. Similarly, changes in industries will call for constant review and renewal of the document guiding the educational curriculum (Yekinni & Ogbuanya, 2025) to keep up with the industrial revolution and changes in society.

Thus, this article examines the trend of industrial revolutions from pre-industrialization through Industry 1.0 to Industry 4.0. It establishes the concept of Industry 5.0 and Industry 5.0 technology and investigates the skills required by workers to adapt with Industry 5.0. The article establishes the concept of engineering education, technology education and technical education and the concept of recurriculation. Finally, the article investigates phases of recurriculation of engineering, technology and technical education programs toward Industry 5.0. Methodologically, this article is anchored on a literature review: existing scholastic empirical reports, theories and opinions.

Industrial Revolutionary Trends

Before the year 1750 which marks the pre-industrial revolutionary period in Europe, people of that age were characterized by their use of hand tools, simple implements and animals to practice subsistence farming and to process and produce essential items, primarily agricultural products, for their proliferation purposes. The period was overshadowed by a poor standard of living and poor economic growth (Durlauf & Blume, 2010; Kent & Kopacek, 2019). Nahavandi, (2019), Odo et al. (2017) and Durlauf and Blume (2010) submitted that between the 1750-1780s, the first Industrial Revolution (Industry 1.0) started in England with the discovery of mechanical power from water, steam, and fossil fuels. The revolution was characterized by different innovations and discoveries viz; coke blast furnaces in 1710 by Abraham Darby, atmospheric engines in 1712 by Thomas Newcomen, steam engines in 1776 by James Watts, flying shuttle in 1773 by John Kay, spinning jenny in 1770 by Hargreaves and water frame in 1771 by Richard Arkwright (Macon-Cooney, 2019). This revolution favored high productivity growth and by extension an increase of GDP per capita, as well as the real wages of people of that period (Macon-Cooney, 2019). Similarly, the revolution led to the liberation of humans from dependence on animal power, and a move from agrarian to industrial and rural to urban societies (Özdemir & Heim, 2018). Second revolutionary changes (Industry 2.0), which began in 1870s, featured the discovery of electricity. Electrical energy coupled with electrically driven machines favoured manufacturers with assembly lines and mass production (Kent & Kopacek, 2019; Nahavandi, 2019). The third Industrial Revolution (Industry 3.0) emanated during the second half of the 20th Century, specifically in the 1970s. The revolution was characterized by computerization and automation in the manufacturing field, hence, giving rise to the application of personal computers, the Internet and ICTs in industries (Ikenga & van der Sijde, 2024; Özdemir & Heim, 2018). During this revolutionary period, automation allowed humans to assign the large number of tasks to machines, leaving supervising and monitoring functions to human beings (Graube & Theuerkauf, 2005). Further advancement and development in information and communication led to the advent of Industry 4.0.

Industry 4.0

Industry 4.0 - The fourth industrial revolution - was an initiative from the German Government in 2011 (Demira et al., 2019, Oeij, et al., 2024). Industry 4.0 includes smart and innovative manufacturing systems where manufacturing is done through the integration of the internet of things (IoT), cyber-physical systems, smart/intelligent machines, artificial intelligence and cloud and cognitive computing (Haleem & Javaid, 2018; Ozdemir & Hekim, 2018; Lu & Xu, 2019). According to Jardine (2020) and Rossi (2018), the objective of Industry 4.0 includes bring together robots, interconnected devices, machines, processes and systems, and fast networks of data within the factory environment, basically to make the factory more productive and execute the routine tasks that can be best done by robots more efficiently and effectively than by humans. The fourth industrial revolution is characterized by the high level of automation, use of cloud technology, big data, more precision as well as miniaturization of products (Cojocariu, 2019; Lewis, 2016; Patches et al., 2019; Ustundag & Cervical, 2018). Industry 4.0 was technologically deterministic (Oeij, et al., 2024). Industry 4.0 dedicated most industrial activities, tasks and operations to the robots (machines), causing larger percentages of industrial workers to become redundant, but created new jobs that required new and emerging knowledge and skills. Correspondingly, Cojocariu (2019) and Vanderborght (2018) claimed that the advent of Industry 4.0 came along with some drawbacks: the complexity of system, expensive software, industrial workers being replaced by machines, security leaks, the need for highly skilled people to operate intricate processes, loss of innovation and creativities and loss of jobs and unsustainable jobs. Also, Acemoglu and Restrepo, (2017), Ford (2015), Kent and Kopacek (2019), Frey and Osbourne (2013) and World Bank (2016) predicted that approximately 47% and 57 % of US jobs and jobs in the OECD countries respectively, will be vulnerable to automation which will in turn have a knock-on effect of reducing customer spending and could result in a secondary wave of job losses affecting all occupations. Correspondingly, evidence upheld that automation technologies replaced workers in both low- and high-skill jobs causing many workers to lose their jobs (Bazylik & Gibbs, 2022; Filippi et al., 2023; Spencer, 2018; Wajcman, 2017). Meanwhile, the situation is unsatisfactory, indicated by reactions in a number of articles dedicated to Industry 4.0 globally (Skobelev & Borovik, 2017).

Humans and Robots

Since the year 2000, computers and machines have been increasingly replacing workers instead of making them more valuable and useful in the developing and developed world (Ken & Kopacek, 2019). The proliferation of robotic automation is inevitable (European Economic Social Committee, EESC, 2018), but Tesla CEO, Elon Musk, admitted that excessive automation in most industries is a mistake, claiming that humans are underrated in industries (Domonoske, 2019; Jardine, 2020). Similarly, Jardine (2020) stated that though robots are much more consistent than humans and better at precision work, robots are inflexible and incapable of adapting to and engaging in critical thinking that is naturally endowed in humans. Thus, by working together with people in industries, robots can fulfill their designated purpose of providing assistance and making lives better (Jardine, 2020). Also, bringing back human workers to the factory floors will pair humans and machines to utilize human brainpower and creativity to increase process and production efficiency by combining workflows with intelligent systems (Ken & Kopacek, 2019; Nahavandi, 2019). Manufacturers who understand the value of human intuition and problem-solving capabilities are positioning themselves to thrive (Anang et al., 2024; Jardine, 2020). Correspondingly, Phill Cartwright, executive chairman of the "Centre for Modelling & Simulation", commented that pairing humans and machines in the manufacturing sector leads to the creation of higher-value jobs than ever before because freedom of design and the associated responsibility is handed back to engineers, technologists and technicians (Kent & Kopacek, 2019). Thus, advocating for the reintroduction of human workers (human intelligence) alongside machines (robots) and collaborative robots (Faccio et al., 2023; Huang et al., 2022; Nahavandi, 2019; Pluchino et al., 2023; Rossato et al., 2021) bring about Industry 5.0.

Industry 5.0

Industry 5.0 is a transformative shift in manufacturing processes that emerged in response to accusations that Industry 4.0 was technologically deterministic, and recognition of industrial workers as substitute or subordinate to machines led to job displacement and removal of human workers from manufacturing processes (Gamberini & Pluchino, 2024, Huang et al., 2022; Leng et al., 2022; Oeij, et al., 2024, Xu et al., 2021). Global Electronic Service (2020), Jardine (2020), Javaid and Haleem (2002), Haleem and Javaid (2019), Ozdemir and Hekim (2018), Rossi (2018), and Skobelev and Borovik (2017) proclaim that the Fifth Industrial Revolution, Industry 5.0, was introduced in 2015. The objective of Industry 5.0 is to continue with the digital transformation of Industry 4.0 with the inclusion of human active roles (Oeij, et al., 2024). European Economic and Social Committee (EESC) (2018), and Patches et al., (2019) described Industry 5.0 as the amalgamation of human creativity and craftsmanship qualities with the speed and consistency of robots. Similarly, Carr and Haslam (1980), Kopacek (2018), Kent and Kopacek (2019), Nahavandi (2019), Patches et al., (2019), and Shelzer (2017) explained that Industry 5.0 is a new industrial change where reliable automation of robots are intertwined with the human brain in a joint operation as human intelligence works in harmony with cognitive computing to increase production efficiency and works as a collaborator and supervisor. Combining the speed and accuracy endowed in automation with the cognitive skills and critical thinking of humans ensures the success of Industry 5.0 (Kent & Kopacek, 2020); Grabowska et al., 2024; Yordanova, 2021). Kent & Kopacek (2019), Demira et al., (2019), Lu (2017), Korcomptenz (2019), Reinhardt et al., (2020) stated that in Industry 5.0, robots rigorously prepare products with high precision, meeting high specification and standards while humans take over to add the value and finishing touches to the product. Machines take over all monotonous, repetitive, error-prone and mundane tasks while humans take creative, artistry, and the research and development side, taking on more responsibilities and increased supervision of systems to elevate and improve the quality of production across the board (Patches et al., 2019; Demira et al., 2019).

Putting humans back into industrial production with collaborative robots will provide humans with bigger opportunities to engage in value-added tasks in production, leading to the personalization of customer needs (Rossi, 2018). Cojocariu (2019); Kent and Kopacek (2019); Ozdemir and Hekim (2018); Østergaard (2018); Patches et al., (2019) state that Industry 5.0 proceeds from mass customization to personalization of customers' needs, where clients/customers are allowed to get products and services by giving them maximum opportunities to state their preferences and requirements based on their needs at the design phase and the production line, instead of choosing from existing options. The most essential benefits of Industry 5.0 include increased productivity, agility and profitability, improved adaptability, change-readiness, a responsive working environment and overall cost reduction (Patches et al., 2019; Kospanos, 2017; Rada, 2018). Industry 5.0 brings improvement to industrial design, process, operations, speed and accuracy of industrial automation through the application of human cognitive and critical thinking capability, which was not previously possible, hence, provides a flexible approach to continuous improvement in manufacturing sectors to solve problems of the future and produce personalised products of high value (Kent & Kopacek, 2019; Ozdemir & Hekim, 2018). Furthermore, Industry 5.0 leads to the attainment of business goals, an exceptionally efficient and value-added production process, flourishing and trusted autonomy and associated costs (Xu et al., 2014; Xu et al., 2018; Haleem & Javaid, 2019).

Technology of Industry 5.0

Global Electronic Service (2020) submitted that the tendency of Industry 5.0 to affect the manufacturing processes and supply chain, among others, depends on quick adoption and the willingness to implement technologies necessary to bring the Industry 5.0 revolutionary features and components to the plant floor. Thus, Burrus (2014), Chattopadhyay (2020), Cojocariu (2019), Nahavandi (2019), Ozdemir and Hekim (2018), Ustundag and Cervical (2018), and Patches, et al., (2019) express that Industry 5.0 technologies, which can be used across diverse professions such as medical science and healthcare, education, sport, entertainment and engineering among others, include customized software/application, network of smart and intelligence sensors, programmable machines and devices, collaborative robotics (cobo), 3D printing, artificial intelligence, internet of things (IoT), cloud technology, blockchain technology and data analytics. Society 5.0 is a society where advanced information technologies (IT), IoT, robots, artificial intelligence (AI) and augmented reality (AR) are actively used in human's everyday life, in industry, health care and other spheres of activity for the progress, benefit and convenience of every human being (Graube & Theuerkauf, 2005; Skobelev & Borovik, 2017). Meanwhile, any change in industries and technologies have severe implications on the qualification, knowledge, skill and attitude of industrial workers. This is because handling these new technologies in industry sectors requires new qualifications and responsibilities and, by extension, new knowledge, skills, attitudes and competencies from industrial workers and management (Saniuk, et al., 2021). Oranu (2010) and Magaji (2015) report that factors responsible for the rising demand for knowledge and skills in industries and labour markets include technological and organizational/industrial change, deregulation of key industrial sectors, and the decline of unions.

Need for knowledge

Industry 5.0 will create new jobs in human-machine interaction and human computational factors (Saniuk & Grabowska, 2022), which may span across intelligent systems, artificial intelligence and robotics, machine programming, machine learning, maintenance, training etc. (Madesn & Berg, 2021; Martynov, et al., 2019). Ikenga and van der Sijde, (2024) and Li (2020) posited that the combined power of humans and machines generates new possibilities and competencies.

This is because, industrial change and rapid changes and developments in technology are progressing globally and in Africa are accompanied by new roles, expectations, activities and tasks. Hence, industries are demanding for managers, workers and graduates with higher and quality education and training standards, multi-skilled graduates and people with new knowledge, skillsets, technical aptitude, attitude, specific and generic skills, in the ever-changing business environment and manufacturing industries (Board of Engineers, Malaysia, 2003; Brunhaver, et al., 2017; Jobs for the Future, 2007; Hernandez-Gantes, 2016; National Academy of Sciences, 2007; National Academies of Sciences, Engineering, and Medicine, 2018). Evidence upheld that employers in the US and other parts of the world began to report problems concerning finding competent workers in high-tech, high-wage fields in science, technology, engineering, and mathematics (STEM), with adequate preparation underlined by basic academic skills, technical skills, and complementary skills associated with teamwork and problem-solving (Carnevale et al., 2010; Hernandez-Gantes, 2016; Hernandez-Gantes & Fletcher, 2013; Ibanga, 2015; Kim, 2011; Otokunefor; 2011). Ikenga and van der Sijde (2024) and Wang, Yu and Han (2021) argued that many workers lack the knowledge and technical expertise to work with new technologies of Industry 5.0 such as artificial intelligence and robotics applications, resulting in a skill gap. Evidence from Demira, Dövena and Sezenb (2019) and Kelly (2015) upheld that people losing jobs in industries are unlikely to possess the education, training, and skills to assume the responsibility of employment requiring creativity in the industrial sector. Similarly, the World Economic Forum (2012) and Spang (2014) reported that it is estimated that there are 10 million jobs in manufacturing companies that remain unfilled due to the skills gap and that the ability to access the right talent will increasingly become a matter of competitive advantage.

According to Hadgraft (2017) and the Institute for the Future (2015), lists of the key skills of the future workforce includes: sense-making, trans-disciplinarity, design mindset, novel and adaptive thinking, virtual collaboration, cross-cultural competency, social intelligence, new media literacy and computational thinking. Demir and Ercan (2019), de Oliveira (2024), Ikenga and van der Sijde, (2024), Kent and Kopacek, (2019), Ramadhani, (2017), Saniuk and Grabowska (2022). Saniuk and Grabowska (2023) identified technical or STEM skills such as understanding of automated systems, robotics, artificial intelligence (AI), the Internet of Things (IoT) and data management software, ability to design, operate and maintain complex equipment and skill to analyse large quantities of data to optimize production processes, and soft skills such as problem-solving, creativity and innovation, flexibility, communication and collaboration, leadership and team management, empathy, emotional intelligence, analytical thinking and innovation, ecological awareness, ethics and social responsibility and knowledge of safety and regulatory compliance, as employee skills needed in Industry 5.0. Similarly, Demira, Dövena and Sezenb (2019); Cojocariu (2019); Alpaslan, et al., (2017); Felder, et al., (2000); Kelly (2015); McCrone et al., (2015); OECD (2015) claimed that job and occupational skills, technical skills, cognitive skills, social and emotional skills, problem-solving, creativity and critical thinking skills are the vital range of skills, demanded by employers in the Industry 5.0 era, and which existing and prospective industrial workers needed to collaborate with smart machines, programme the robots, or manage them.

Thus, Industry 5.0 created new types of work and introduced new technologies which require workers with highly developed knowledge and set of skills and proficient in the use of these technologies (Greenwood, 1997; Kent & Kopacek, 2019; Kopacek, 2018). Global Electronic Service (2020) stated that the birth of Industry 5.0 requires new manufacturing roles such as Chief Robotics Officer (CRO) and experts who are knowledgeable, skilful, specialized, and focused on human-machine connectivity and responsible for making decisions on which machines or devices can be added to the plant floor to improve strategies for optimizing the production line. Similarly, Ramdass (2012) reported that the most significant demand of any industry are highly skill workers who possess the strong ability to apply new knowledge and technologies, and who can bring about business improvement methodologies and ultimately add value to industrial output. Correspondingly, Özdemir and Hekim (2018) expressed that both industrial personnel and students (prospective industrial workers) in the field of technology and engineering ought to be exposed to and experience the emerging concepts and knowledge of the IoT, AI, smart factories, and how they might transform and implement the knowledge within Industry 5.0 in the near future. Meanwhile, these skills are indisputably lacked by most serving and prospective industrial workers (Akinyemi et al., 2012; Ibanga, 2015; Otokunefor, 2011; Ogbuanya & Onele, 2018). Nahavandi (2019) claimed that essential skill/role gaps which exist as a result of Industry 5.0 emergence must be addressed.

Evidence upheld that Industry 5.0 changes career and professional development, emphasising the need for new skills, continuous learning, and adaptability in a rapidly evolving labour market (Huang et al., 2022; Tomaseic, 2023). Consequently, there is an urgent need to focus on the role of education and training as a lever for a competitive, innovative, sustainable and inclusive labour market and economy (Oeij, et al., 2024). This is because the design and implementation of quality education and training for industrial workers (engineers, engineering technologists and engineering technicians) are pivotal for personal, national and international development (Board of Engineers, Malaysia, 2003).

Technology is continuously playing a considerable role in Industry 5.0, there is corresponding increase in the need for up-skilling and re-skilling the workforce with a background in STEM-soft skilled training (Ikenga & van der Sijde, 2024) to enable them adapt to Industry 5.0's changing requirements and help businesses succeed in this new era of production (Demir & Ercan, 2019; Güˇgerçin & Güˇgerçin, 2021). Ramdass (2012) expressed that the essential skills, knowledge, attitudes and capabilities needed to excel in industries globally and, in Africa, are developed and learned through the institute or faculty of engineering and technology in higher education. This is because an educational/training institution is an institution of learning devoted to the discovery, examination, production, appraisal, dissemination and transmission of knowledge (Erguder, 2010; Steyn, et al., 2012) to develop the human potential that supports the social, economic, cultural, and intellectual life of a rapidly changing society, and ensure high-level skills training and development of personal abilities that would support national development (Federal Republic of Nigeria, 2013; Ramdass, 2012). Building these knowledge and skills requires human solid capital foundations and lifelong learning because human capital is positively correlated with the adoption of advanced technologies (Kent & Kopacek, 2019). Similarly, Jonathan and Monday (2017), Koretsky and Magana (2019) and Parashara & Parashar (2012) reported that there is a need for a higher level of skills and knowledge of technology used in engineering practice to be taught as advanced learning, before workplace entry, to cope with and manage rapid changes in technology and industrial changes, uncertainty and complexity in the workplace.

Graube and Theuerkauf (2005) expressed that the emerged developments in engineering and technology have significant implications and impacts on engineering, technology and technical education. Educational institutes such as universities, polytechnics, institute of technology and technical colleges play a significant role in preparing a potential workforce (engineers, technologists and technicians) who can fulfil an ambassador's role in Industry 5.0 (Oeij, et al., 2024). Scholars upheld that knowledge, skills and attitudes needed to cope with the advent of Industry 5.0 are offered primarily at educational institutions' classrooms and workshops/ laboratories purposely to meet national developmental goals and global demands, support critical discourse and creative thinking, and support the advancement of all forms of knowledge (Department of Education, 1997; Lange, 2012; Resale, 2019). However, educators and policy makers have come to a consensus that the ability of engineering, technology and technical education to provide such training needs to be promoted and improved (Katehi et al., 2009; Parashara & Parashar, 2012). This study focuses on development of technical, technology and engineering education in universities, polytechnics, institute of technology and at technical college level for the purpose of producing competent engineers, technologists and technicians who work at industries in Nigeria.

Engineering Education

Conceptually, the Board of Engineers, Malaysia (2003) and Sönmez (2014) proclaimed that engineering education programs are expected to instil in students the ability to apply mathematics, science and engineering science in the design, operation and improvement of systems, machines and processes to meet desired needs; conduct experiments; analyse and interpret data; identify, formulate and solve engineering problems; understand and resolve the environmental, economic, societal implications of engineering work; engage in lifelong learning and professional development, and act under the ethical principles of the engineering profession. According to the Board of Engineers, Malaysia (2003) and Cheshier (1998), engineering education focuses on the conceptual and theoretical aspects of science and engineering which is aimed at preparing potential graduates for the practice of engineering in research, development, and conceptual design functions. Though scientific and technological knowledge and skills are available in engineering educational programs, engineers are expected to be equipped with the capability necessary to participate in research, develop functional devices, structures or processes, design work, production and testing, sales, management, consulting and teaching and also framing the curricula of engineering programs (Eide et al., 2008; Sönmez, 2014; Wickert, 2006). Similarly, participation in engineering programs at university and college level helps to improve a student's level of ability to apply mathematical reasoning within the design process (Akins & Burghardt, 2006; Gomez-Zwiep, 2016). Meanwhile, an educational program similar to engineering education is technology education.

Technology Education

Technology education programs at university and college level are designed to prepare students in grasping knowledge of system and their components, technical operations and actions, functions of technical systems and processes, consequences for the individual, and the history and development of technology (Graube*,* 2005, Lindstrom, 2005). Technology education aims to develop in students the creative, imaginative, technical and practical expertise needed to solve real and relevant problems confidently, and to participate effectively in technological world; build and apply a collection of knowledge and skills via manipulation of materials and tools with techniques to design and make high-quality prototypes and products for a wide range of users; and critique, evaluate and test their ideas and products (Ankeli, 2019, Department for Education, 2013, James et al., 2015). Generally, technology education instils in students the ability to know and understand technical systems and processes (structural, functional, societal, historical, ecological, economic, aesthetic qualities of a system etc.), ability to manage technical systems (including all forms of operations: design, production, management, removal from operation, recycling technical systems), and ability to assess and evaluate the social, human and environmental impact of technical products, systems and processes (Schlagenhauf, 2005). Graube and Theuerkauf (2005) stated that technology education is designed to enable students be part of the process in which a world undergoing technical change has to be given shape, be capable of responsible technical action, cope with technological /practical requirements encountered in our daily lives and on the job, understand the principles of technical systems, and be able to use their basic technical understanding to decide in favour of technical professions. Technology education primarily emphasises the analysis, application, implementation, and improvement of existing technologies and is aimed at preparing prospective graduates (technologists) for the practice of engineering closest to product improvement, manufacturing and engineering operational functions (Board of Engineers, Malaysia, 2003; Cheshier, 1998). Similarly, technology education aims at producing graduates (technologists) who understand how conditions of production, society, the physical environment, and the requirements of life are changing (Blomdahl, 2005).

Technical Education

The Federal Government of Nigeria, FGN, (2004), Jonathan and Monday (2017), Magaji (2015), McCrone et al., (2015) and Winer (2000) define technical education as the study of technologies and related sciences and acquisition of practical skills, attitudes, understanding, work habits and knowledge that enables the learners to gain employment and perform effectively in employment on a valuable and productive basis. Okoye and Arizona (2016) and Uwaifo (2009) submitted that technical education is the training given to students to become technically oriented personnel who are to be the initiators, facilitators and implementers of the technological development of a nation. The purpose of technical education is to prepare youth and adults for careers in a wide array of high-wage, high skill, high-demand fields (Association for Career and Technical Education (ACTE), 2014; Hernandez-Gantes, 2016). Technical education prepares people for entry into recognized occupations at a higher level but usually lower than the first degree (Okoye & Arizona, 2016).

Engineering, technology and technical education are designed to train students in classrooms and workshops/laboratories for their specific career major (Altalbe, 2018; Yekinni and Ogbuanya, 2025). Specifically, engineering, technology and technical education are typically offered at the institutes of technology, polytechnics, universities, local community colleges, trade centres or technical colleges (Odo et al., 2017), leading to the turning out of engineers, who design the system and process, technologists, who use scientific and practical knowledge to implement design and change design into product, and artisans and technicians who install and maintain the product and are conversant with engineering related ethics (Felder et al., 2000; Ogbuanya & Yekinni, 2019; Zambwa et al., 2018) and who can gain employment mostly in industries, an establishment or become an entrepreneur (The Institution of Engineers, Australia, 2002; Okoye & Arizona, 2016; Momo, 2012).

The training given to engineers, technologists and technicians can either be on-the-job/ in-service training, which implies current and existing industrial service personnel undergo further training; placements; mentoring activities; attending trade shows; visits; competitions), manufacturer training (for better performance and career/professional growth and development) or off-the-job/pre-service training, learning at college or with the learning provider. (Lucas & Spencer, 2015; McCrone et al., 2015; Ciraso-Calı et al., 2016). By implication, professional engineers focus on the design and development of products, or systems; engineering technologists are inclined to apply engineering output in manufacturing and production line (Board of Engineers, Malaysia, 2003; Cheshier, 1998; Sönmez, 2014). Meanwhile, engineering technicians are expected to have relatively practical understanding of theoretical principles and be proficient in applying relevant skills and techniques for carrying out installation, maintenance and repair activities in industries or an establishment (Francois, 2005; Ibezim, 2011; Ogbuanya & Yekinni, 2019; Ohanu & Ogbuanya, 2014; Zambwa, 2018).

Challenges Facing Engineering, Technology and Technical Education Institutions

Engineering, technology and technical education graduates of the present day are commissioned to solve the problems of a future world that faces a rapidly increasing and more critical than ever set of challenges (Atman et al., 2010; Korkmaz et al., 2018). Okoye and Arizona (2016) and Umunadi (2013) explained that training of engineering and technical personnel in most institutes of technology, polytechnics, universities, local community colleges, trade centres or technical colleges in Africa, including Nigeria, have witnessed many challenges such as a curriculum that has little or no relationship with workplace and social needs, inadequate facilities and poor staff training among other things. Similar evidence upheld that Zimbabwe, Malawi and Tanzania have identified inadequate learning facilities, absence of school-industrial synergies and ineffective curricula among other constitute problems facing educational institutions struggling to produce competent graduates (Lemo & Olakotan, 2016; Olakotan & Lemo, 2019; Woyo, 2013; Anangisye, 2008). Similarly, Chattopadhyay (2020) expressed that educational institutions globally, including Nigeria, face significant challenges - a function of tectonic shifts and technological disruption in the techno-socio-economic landscape and digital revolution frequenting in industries which causes professionals to find themselves becoming irrelevant in their career, professional and occupational areas.

Meanwhile, experts claimed that educational changes must be kept up with new technologies and changes in industrial requirements (Kline, 1992; National Academy of Sciences, 2005). Similarly, experts asserted that educational institutions through their academia should work with industries to produce and align curricula with real-world needs, up-skill workforce and ensure engagement with ongoing changes (Carminati et al., 2025; Yoto, 2017). To cultivate and synergize Industry 5.0 knowledge and skills into education and training programmes, there is need to revise current teaching and training programs (Carminati et al., 2025) and incorporate technologies such as artificial intelligence and machine learning etc. into Industry 5.0 applications to tailor the educational experience for learners in education programmes (Ikenga & van der Sijde, 2024). Scholars expressed that amidst the ever-changing work milieu, there is a need for educational reforms focusing on improved career readiness nationally and internationally (Hernandez-Gantes, 2016; Stone, 2013) in which schools have to provide learning experiences in areas like digital skills, numerical competencies, scientific and technological know-how, entrepreneurship, machine learning, data analysis, artificial intelligence, programming among others that can make students fit in their occupational area after graduation (Galvao et al., 2017; European Parliament and Council, 2006; Ramadhani, 2017). Engineering, technology and technical education graduates are naturally expected to possess a number of integrated skills (Korkmaz et al., 2018). Therefore, there should be a cordial relationship between the quality of graduates produced and supplied by educational institutions and the need/demands of the industries for the purpose of bridging the need gap of skill labour (Priyowirjanto, 2001; Yoto, 2017). Thus, experts highlighted urgent needs to re-skill professionals such as engineers, technologist and technicians in the Industry 5.0 era and to make the transition of students from school to industry smoother and less traumatic by re-booting and making the curriculum, pedagogy of teaching/learning and faculty members more relevant to the world of industry and commerce (Chattopadhyay, 2020; Moss, 1990; National Academies of Sciences, Engineering, and Medicine, 2018). Thus, this article focuses the development of a model for redesigning the academic program of study in the Nigeria educational institutions (institutes of technology, polytechnics, universities, local community colleges, trade centres or technical colleges) for the production of competent engineers, technologists and technicians who are proficient to adapt to an Industry 5.0 technological shift.

Curriculum would include components such as the rationale for the program, conceptual and contextual knowledge structures, learning outcomes, teaching and learning activities, assessments, level descriptors and graduate attributes etc, that would address the knowing, doing and being imperatives of a graduate (Scholtz, 2013). Nkomo (2000), Scholtz (2013) and Wattanbarger and Skaggs (1979) proclaimed that curriculum is virtually every aspect of the full education system. If the curriculum becomes obsolete and antediluvian due to technological and industrial changes, it must be revised. Similarly, experts upheld that to keep pace with the rapid evolution of technology and knowledge explosion, to cope with shifting social expectations, to make students relevant and provide them with the current development in practices and theories, to produce self-directed learners, critical thinkers and workers who will be able to work in a team and contribute to the entire development, it is imperative that the curricula of the discipline are reviewed and renewed regularly (Carew & Cooper, 2008; McInerney, 1998; Ramadhani, 2017; Resane, 2019). This is because experts expressed that curriculum needs regular revision, reform and renewal to ensure that the needs of learners are adequately addressed (Meliani et al., 2021; Resale, 2019; Supriani et al., 2022), meet the constantly changing training needs that keep up with technological change and industrial development in every engineering, technology and technical educational institution, maintaining the current quality of educational programs and meet up with the current demands of culture, society, industries and the expectations of the population it is serving (Carew & Cooper, 2000; Johnson, 2001; Subasubani, 2016).

Thus, the fundamental step for the development of engineering, technology and technical education programs in the Industry 5.0 era, is the revision and improvement of a curriculum to make it more relevant, current and improve the supply base of employable candidates to industry (Ramdass, 2012). Guan and Lu (2012) and Lu et al., (2013) expressed that it is essential to understand industrial needs, design a curriculum that has qualities to bridge the need gaps, and cultivate human resources to meet these needs. Changes in technology and industrial expectations, due to the advent of Industry 5.0, called for urgent recurriculation and overhauling of engineering, technology and technical education qualification framework with the view of meeting the needs of 21st century educational programs that are more responsive to the socio-economic development of our society (Forbes, 2006; Johnson et al., 2012; Lu et al., 2013; Okoye & Arizona, 2016; Ramdass, 2012; Schultz, 2013). This will also respond to the demands of national and global policies, goals and objectives and to the requirements of higher educational institutions, industries, professional bodies and general economy (Schultz, 2013). Similarly, Sönmez (2014) opined that engineers, engineering technologists and engineering technicians should acquire more comprehensive trainings that will enable them to adapt to and adopt technological innovations, and to successfully participate in a globally competitive business world via restructuring engineering, technology and technical education programs and curriculum. Thus, the process of restructuring the curriculum, is Recurriculation.

Recurriculation of Engineering, Technology and Technical Education Programs

It is good to acknowledge that nearly all the studies consulted online or offline on recurriculation of academic programs were conducted and reported from South African educational institutions. Conceptually, recurriculation is a curriculum transformation which represents a strategic effort to advance technical, technology and engineering education programs with an aim to prepare graduates who are proficient to adapt with Industry 5.0 technology (Harden, 2001). Recurriculation of engineering, technology and technical education programs, which are synonymous with curriculum revision, refers to modification or re-adjustment of existing curriculum to produce modern and appropriate objective, content, and process driven curricular that support the maintenance of the quality of engineering, technology and technical education programs and production of graduates who can flourish in their chosen profession (Burgess, 2004; Carew & Cooper; 2008, Ramdass, 2012; Schultz, 2013). Recurriculation is the establishment of a new curriculum that addresses the number of weaknesses of the existing curriculum (Council on Higher Education, 2013) and refining the curriculum to better address the needs of industry and society at large (Van As et al., 2016). Recurriculation includes the introduction of a new learning experience in which its purpose, outcomes, field of study, mode or site of delivery have changed significantly to comply with both industrial, technological and societal demands (Resale, 2019). Pressure exerted on institutions of learning to enhance students' learning and train future workers who possess necessary skills and knowledge needed to engage actively in industry, adapt to new technology such as robots in industries and necessitate recurriculation of engineering, technology and technical education programs in Nigerian institutions (Prochario-Foley, 2017; Resane, 2019).

Recurriculation of engineering, technology and technical education qualifications frameworks will undoubtedly translate to the production of highly qualified and competent graduates - engineers, technologists, artisans and technicians - who are better prepared to meet the challenges of a constantly changing workforce in Nigeria and by extension promote rapid industrialization and economic growth of national and global society (National Academy of Sciences, 2005; Okoye & Arizona, 2016). Recurriculation is necessitated by the need for genuine curriculum change that demands a deeper enquiry into the kinds of knowledge, skills, values, attitudes and beliefs that can meet and respond to Industry 5.0 demands in Nigeria (Jansen, 2012; Resane, 2019). Evidence upheld that key drivers of the Future Work Skills in engineering and technology, especially in Nigeria, include a computational world of AI and big data, super structured organization, increase of smart machines and systems, new media ecology, and a globally connected world (Institute for the Future, 2015; Hadgraft, 2017). Thus, the advent of mechatronics, smart/innovative technology, Nano-technology and sustainable development (greening) technology which are the components of Industry 5.0, have forced experts in the field of engineering and technology – Electrical/Electronic Engineering (Technology), Mechanical Engineering (Technology), Building and Civil Engineering (Technology), Chemical Engineering (Technology), etc. - to embark in the universities and colleges on the revitalization of their curriculum. Specifically, metalwork, auto mechanic technology and mechanical engineering are introducing elements of mechatronics into the program of undergraduate and postgraduate students. This is helping mechanical engineering students to gain more knowledge and skills relating to the design, development and application of robots in industries. Electrical/Electronic engineering accepts programming languages, cyber security, nanotechnology and its application, and greening technology into the program. Similarly, chemical engineering introduces students to the application of nanotechnology, chemical plant design and fractionating columns, and application of electronic equipment and devices in the chemical engineering laboratories, such as spectrophotometer (for microbial counting), centrifuge machines (for the separation of liquid components), electronic ampoule/ampule (ceiling of chemical sample for storage and preservation purpose etc). These changes bring about the recurriculation of academic program in the field.

Postmodern Curriculum Theory

Globally, technology and industry are undergoing post-modernisation – an idea for referencing a world without stability, where knowledge is constantly changing and change is the only constant (Boboc, 2012; Nădrag & Buzarna-Tihenea, 2015). Thus, William Doll, the prominent American curriculum theorist proposed a postmodern curriculum theory to address the continuous changes in knowledge and skills demanded by employers due to industrial revolution and technological changes to equip the prospective workforce of industries. The article adopted postmodern theory since the article focused on the changes in knowledge and skill that may exist as a result of migration from Industry 4.0 to Industry 5.0.

Postmodernists (Doll, 1993; Gang, 2015; Lau, 2001; Lixin, 2004; Negroponte, 1995) suggested the 4R's - Richness, Recursion, Relations, and Rigor - as criteria for the recurriculation of engineering, technology and technical education programs. Conceptually, Richness of curriculum entails quality of curriculum instead of quantity (Lixin, 2004). Lixin (2004), and Whitehead (1967), argued that curriculum content should be few and crucial. Richness according to Smitherman (2005), and Schultz (2013), stands on the premise that curriculum is revised to enrich its content, knowledge, skill and attitude and to be inculcated to make it fit, be relevant and pertinent to technological and industrial changes in the Industry 5.0 era. Recursion here revealed that recurriculation of an existing academic program (curriculum) occurs to transform and change the existing curriculum to one that can promote and support new/current experience, skills and knowledge and, by extension, foster genuine creativity in students iteratively by using the current curriculum as a basis for the formation of a new curriculum (Smitherman, 2005; Schultz, 2013). Here, the existing curriculum is revised and changed considerably to produce new curricula to maintain the stability of the existing patterns but with changes in variables (Doll, 2013; Godden, 2014). This includes those elements within the new curriculum – the matrix or network which gives new curriculum richness and, those outside school, a large matrix within which the curriculum is embedded (Doll, 2013; Doll, 1993). Lau (2001), Doll (1993) and Doll (2013) stated that relationships might be pedagogical relationships (interactions among the curriculum structure) or cultural relationships (interactions among the curriculum with the local as well as global context). Technology and industry are ever-changing, ever-shifting and dynamic, hence, affecting how curriculum is constantly shaped and structured. Finally, Rigour means that recurriculation must involve critical analysis and examination of content, knowledge, skills, attitude and competence to be embedded in a new curriculum to determine its relevancies and fitness, and address technological and industrial change (Smitherman, 2005; Schultz, 2013).

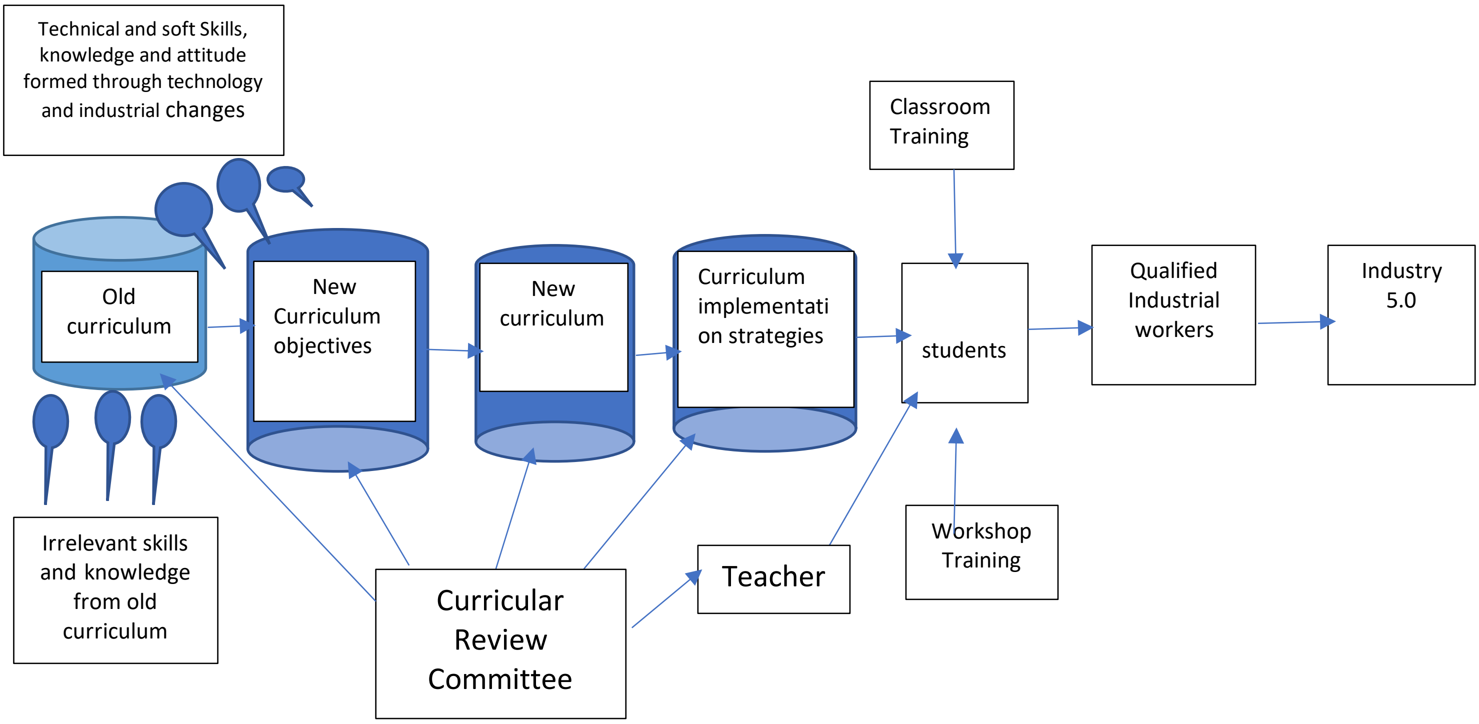

Figure 1: Recurriculation model

The model above depicts that for appropriate recurriculation to occur, curriculum Review Committees are formed, which include engineering educators, policymakers, industrial employers- educational researchers, etc who are responsible to extract and use some of the relevant knowledge, skills and attitude from the old/existing curriculum, and technical or STEM skills, soft skills, occupational skills, and cognitive skills, knowledge and attitude due to technological and industrial changes as input for stating the objectives of new curriculum and for producing new curriculum for institutes of technology, polytechnics, universities, local community colleges, trade centres or technical colleges. Thus, the new curriculum will be used to train the students in the classroom and well facilitated workshops/laboratories through qualified teachers using appropriate pedagogical methods. This is mainly to produce qualified and competent graduates who will conveniently work in Industry 5.0.

Phases for the Recurriculation of Engineering, Technology and Technical Education Programs.

The process of recurriculation, as reported by Aguokogbuo (2000), Katehi et al., (2009), Okeke (1981), Starbuck (2016) and Supriani, (2022), includes: constant brainstorming, reviewing, analysis and evaluation of existing engineering, technology and technical education programs and societal needs, identification of aspects of the program to be revised, involving all concerned with the planning, development and interpretation and implementation of curriculum, development of curriculum content, skills, tasks and trade, and production of actual curriculum materials and production of curriculum packages. Thus, after reviewing a number of published works, the phases of recurriculation of engineering, technology and technical education programs is addressed in the chronological order as follows.

Senior management brainstorming and reviewing Industrial's needs

Openness to Change

In deciding to embark on curriculum renewal, innovation or review in engineering, technology and technical educational programs, it is vital to consider the readiness of the academics, instructors and other actors for change (Carew & Cooper, 2008). Here, academics should willingly accept the changes to prevail or accept the changes to take place in the educational system before any curriculum review can be successfully done in engineering, technology and technical education programs. Experts revealed that the ultimate requirement for curriculum innovation is the creation of a culture of openness to change and wiliness to adapt to new technology and work process (Jackson, 2002; Ikenga & van der Sijde, 2024; Schultz, 2013; Wattanbarger & Skaggs, 1979). Academics and other actors who have undertaken recent curriculum change may be suffering from change fatigue and have inadequate resources of patience and enthusiasm to participate in more change (Carew & Cooper, 2008). The openness to change will create more eagerness to participate in the recurriculation process. Similarly, changes in educational structure and individual functions and responsibilities are likely to occur if curriculum changes are accepted among academics in educational institutions. Openness to change includes the willingness to be part of a curriculum review committee, readiness on the part of engineering, technology and technical educators to take part in professional development that may enable them to teach new courses/subjects in the classroom or workshops/laboratories effectively, and readiness, on the part of engineering, technology and technical education workshop instructors to undergo training on how to operate new equipment and carry out new task/activities in the laboratories/workshops. For instance, automobile lecturers and instructors may be trained on how to use automobile diagnostic scanners while mechanical engineering lecturers and instructors may be trained on how to handle Finite Element Analysis (FEA) software, Computer-aided design, and Computer Numerical Control machine among others.

Formation of Curriculum Revision/Recurriculation Committee

Aguokogbuo (2000), Beane, Toepfer and Alessi (1986), Irons, Holm and Annandale (2017), Johnson (2001), Katehi, Pearson and Feder (2009), Özdemir and Heim (2018), Schneider and Rivet (2000), Spang (2014), Ilkiw et al. (2017), Isabel and Stewart (1935), Wattanbarger and Skaggs (1979) expressed that the task of recurriculation is conducted by and committed to the hand of various concerned experts and stakeholders of a Curricular Review Committee. This committee includes engineering/technology educators, policymakers, industrial employers-financial investors, industrial engineers, smart factory entrepreneurs, content experts and information and communication technology (ICT) experts- educational researchers, curriculum experts and cognitive scientists and others concerned about the development of the country’s technical workforce will also find much to ponder. Committees consist of an assortment of field-relevant work representatives and the academic staff of a department who decide upon curriculum issues so that the academic courses are more closely aligned with what work wants, and to changes that are occurring in the industry (Garraway, 2007). Curriculum review/recurriculation committees are charged with the responsibility to conducts a series of workshops to identify new institutional goals, aims, objectives and philosophical statements, technical and non-technical skill sets, deliberate on the lack and needs of the existing curriculum, determine the extent of changes to be done on existing curriculum by determining and selecting the irrelevant knowledge, skills and competences to be removed or identify the new skills that could be added to the curriculum and come out with new curriculum that is in alignment or matches with the latest technological and industrial development (Aguokogbuo, 2000; Irons et al., 2017; Spang, 2014; Thanikachalam, 2015). The function of this committee also includes the identification of problems, issues, and concerns of the previous engineering/technology-related curriculum and use the information obtained to come up with a better curriculum that addresses the needs of fast-growing industries (Ilkiw et al., 2017). The committee of experts will identify the trades in engineering and technology fields, roles/job description, activities and tasks required in each trade and competences, skills and knowledge needed to perform the tasks. Committees will set the time limit for knowledge and skill acquisition and decide on orderliness of skill acquisition and its arrangement on the curriculum.

Development of Outcome Statement

Program Outcome Statements are statements that accurately describe what students from a engineering, technology and technical education academic program will be able to do at the point of graduation (Carew & Cooper, 2008). This phase includes the establishment of rationale, philosophical, general and institutional outcome statements, core values, guiding principles, and learning outcome statement that addresses core and specific knowledge, competencies, skills and attitude that are relevant and fit for the industry 5.0 (Aguokogbuo, 2000, Beane, Toepfer & Alessi, 1986; Ilkiw et al., 2017; Taba, 1962). Golby (1977) and Beane, Toepfer and Alessi (1986) stated that curriculum goals imply statements of preferences, values and judgments about the directions which engineering, technology and technical education activities might focus. Meanwhile, specific objectives reflect short or immediate purpose involved within a particular classroom/laboratory teaching and learning activities (Beane et al., 1986). Irons, Holm and Annandale (2017) stated that at this stage, curricular review committees finalize the general and specific objectives and outcomes of the engineering, technology and technical education academic programs. The sample of program outcomes could include, at the end of an academic program, graduates should be able to:

1. demonstrate knowledge, understanding, and proficiency regarding the selection and choice of appropriate smart tools, equipment and materials in design and construction of functional electronic circuits safely,
2. select and use appropriate electronic tools, equipment and material in the repairing and maintenance of electronic equipment and appliances,
3. design a functional miniature circuit
4. write a functional algorithm for the design of robot.
5. design simple robot using appropriate materials and equipment
6. carry out crystallization, filtration and evaporation processes safely using appropriate methods, materials and equipment.
7. use Finite Element Analysis (FEA) software to perform structural analysis on stresses and deflections in complex structures.
8. handle Computer-aided design for the creation, modification, analysis, or optimization of design.
9. design roads for light vehicular traffic, taking into account vehicular loading, existing ground properties, local environmental conditions, and local availability of road building materials, machinery, labour and expertise (Carew & Cooper, 2008).

Development of content

Curriculum committees reflect on the contents of a curriculum to ensure that it meets the demands posed by technological and industrial changes, and the unique context of the country - Nigeria (Council on Higher Education, 2006; Steyn et al., 2012). Here, the curriculum committee decides on what should form the learning experience of engineering, technology and technical education students and how such can be arranged, structured or mapped using program outcome statements as a guide. This involves identification and definition of required experience that can help to develop the required skills, knowledge, behaviour, competencies and attitude needed to gain employment in industries (Beane et al., 1986). Colin (2009), and Walker (2003) argued that curriculum should include content that may be depicted in terms of concept maps, topics and themes. Golby (1977), Olaitan (2003), World Health Organization (2019), Starbuck (2016) stated that this stage includes the addition and formation of relevant programs, topics, course structure and method, scope, sequence, or modules to suit the ideas, knowledge, skills, attitudes and competencies expected from engineering, technology and technical education graduates to gain employment, and function productively in industries. This also includes the establishment of laboratories/workshops, tasks/activities, classroom tasks/activities, library, specification of kits, resource units, text and other teaching and learning materials that support the knowledge and skills to be acquired by students of engineering, technology and technical education programs (Aguokogbuo, 2000; Golby, 1977). Hlavac (2023), The Government of Western Australia (2025) and Thanikachalam (2015) claimed that every industry publishes the desired knowledge skills and competencies required from the employees from time to time, hence, these should be considered as standards by the trainers for the recurriculation of engineering, technology and technical education programs. Specifically, the Government of Alberta (2024) identified Interpret drawings, Interpret specifications, layout projects using drawings and/or specifications; apply applicable standards, regulations, and codes; demonstrate safety awareness and safe work practices; select, use, and maintain personal protective equipment; select, use, and maintain hand and power tools; demonstrate start-up and shutdown procedure of oxyfuel equipment, use oxy-fuel equipment when cutting metals, and use oxy-fuel equipment when heat straightening metals among others as competencies required to train an Ironworker Metal Building Systems Erector.

Pedagogy

Pedagogy is the art of arranging teaching and learning processes to achieve specific learning outcomes among learners (Coral, 2009). This involves an arrangement of learning methods and techniques that engineering and technology teachers, trainers and instructors adopt during teaching and learning situations in classrooms and laboratories/workshops. This is the implementation period where skills, knowledge and attitude are arranged and taught to students both in the classroom and workshops/laboratories. The teacher, before training, states achievable and specific objectives. Then, teachers use objectives as a guide in delivering the contents of instruction in the classroom and laboratory using appropriate methods and techniques and teaching aids. The methods that are often used by engineering and technology educators and instructors during classroom and workshop teaching and learning activities includes: bringing an expert to teach in the classroom or workshop, guiding students to practice specific tasks inside the workshop, hands-on learning, feedback which promotes learning, real-world problem solving, one-to-one coaching and mentoring, competing against the clock, and seamless blending of online and face-to-face learning (Lucas & Spencer, 2015; McCrone et al., 2015).

Professional Development

Engineering, technology and technical education teachers and instructors educate and train male and female youths within the institutes of technology, polytechnics, universities, local community colleges, trade centres or technical colleges level, who are or will become employees of industries in Nigerian society (National Academy of Sciences, 2005). The knowledge and skills that teachers/ laboratory instructors require to carry out their duties change with new challenges and shifts of technology and industrial revolutions (Okeowo, 2009). Thus, as educational programs evolve to meet the changes in technology, markets, and societal needs, faculty members must be trained on new teaching and learning techniques as well as new technology and essential professional skills that their students will encounter in the workplace (National Academies of Sciences, Engineering, and Medicine, 2018). This is because, Chai et al., (2017), Göksün and Kurt (2017), Kennedy et al., (2022) and Wagiran et al., (2019) stated that improving the skills for teaching and learning processes among teachers are vital for improving the integration of new technologies in technical, technology and engineering education programs to enhance the attainment of educational objectives. Aguokogbuo (2000), Golby (1977) and Subasubani (2016) reported that the need for continuous pedagogy and didactic training and retraining of engineering, technology and technical educators could not be underestimated, because delivery methods of lessons are as critical as the level of knowledge of the subject the trainer has. A lack of teacher preparedness and further training among technical, technology and engineering education teachers and instructors poses a serious challenge on them to shifting from traditional teaching methods to modern ICT-based teaching methods (Edwin & Stela, 2016; Carr et al., 2018; Kennedy et al., 2022). Thus, experts supported that the educators and instructors who are tasked with the responsibility of implementing curriculum in Nigeria need to attend professional development sessions to teach engineering, technology and technical education related subjects efficiently (Katehi et al., 2009). This makes them continuously fit and relevant in the implementation of new changes in curriculum and by extension, makes them qualify to foster genuine creativity in students (Okeowo, 2009) and produce graduates that will be accepted in industries.

Eggen and Kauchak (2006), Kipper and Rüütmann (2013), Gess-Newsome (1999) and Shulman (1987), reported that during professional development, at least four different forms of knowledge are essential for technical, technology and engineering educators while teaching for understanding:

Knowledge of content – this means a thorough understanding of the topics and subjects taught by teachers in all content areas. Foster (2020) stated that Subject Content Knowledge include understanding the substantive and syntactic structures of concepts, principles and, ultimately, facts of any given subject area. For instance, electrical/electronic engineering/technology/ trade teachers should have deep knowledge of electrical/electronic components, have ability to use measuring devices and equipment such as multimeters, oscilloscopes, clamp meters, vectorscopes, tachometers, and chronometers, and build a circuit among others.

Pedagogical content knowledge – this includes the ability of teachers to create examples, understanding of ways to represent subjects that make it understandable to students and knowledge of what makes the learning of specific topics easy or difficult (Atkins, 2025; Shulman, 1986; Shing et al., 2015). It also includes 'blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of students and presented for instruction. This includes appropriate adoption of teaching techniques and strategies to deliver content of instruction. For instance, engineering/technology/trade teachers or instructors may use demonstration method in teaching product design, construction and analysis in laboratories/workshops. However, explanation method may be applied to clarify the concepts theories and principles of particular topics.

General pedagogical knowledge – this implies understanding of general principles of instruction and classroom management that transcends individual topics or subject matter areas. Similarly, teachers with this knowledge should be able to communicate clearly, provide effective feedback, and use other strategies that make teaching in classrooms and laboratories more meaningful. The knowledge may help the engineering/Technology/trade teacher to arrange the classroom and laboratories appropriately prior to the commencement of the teaching and learning instruction, have background understanding of students and adopt appropriate strategies to assess students' level of instructional achievement (Weyers et al., 2024).

Other categories of teacher knowledge include curriculum knowledge, knowledge of educational contexts, and knowledge of educational ends, purposes and values. (Shulman, 1987).

Implication of the study

This article synthesized the scholastic opinions and reports of the previous studies on recurriculation of engineering, technology and technical education programs for adopting Industry 5.0. The article has implications on educational stakeholders, specifically STEM educators, school administrators, policy makers and governments. The article exposes educational stakeholders - educators, school administrators and policy makers to historical trends of industries. The article informs the educators, policy makers and government of the current industrial era that these are features and qualities of the era. This will help the educators to engage in training that will make them fit for the changes, encourage government to offer necessary supports and adequate funds to equip the schools and training the teachers to cope with changes appropriately, and stimulate policy makers to enact favorable polices that will promote adequate adjustment to the current industrial era. The article will inform teachers, school administrators and government on the needs for the recurriculation of existing/current educational programs and inform them of steps/phases of recurriculation of existing/current educational programs. This will help them to understand the roles expected of them during the recurriculation process.

Conclusion

The advent of Industry 5.0 was accompanied by new requirements, new roles and new tasks. These make the knowledge and skills possessed by industrial workers stand obsolete and, by extension, make them irrelevant and unfit for industrial jobs in this era. This is because the old knowledge and skills they possessed could no longer be useful in industries these days. However, this article presents Industry 5.0 in a holistic form, establishing the need for knowledge and skills in the Industry 5.0 era. The article conceptualized engineering, technology and technical education, and the challenges they are facing in addressing Industry 5.0. The article conceptualised recurriculation of engineering, technology and technical education and finally, detailed phases of recurriculation in engineering, technology and technical education.

The recurriculation, if accepted by engineering, technology and technical education administrators in the universities and colleges of engineering and technology globally, will promote the turning out of graduates who are competent and qualified to work conveniently with robots in industries.

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