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Engineering Education and soft skills in the Era of the Fourth Industrial Revolution in Africa

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***Abstract:** The Fourth Industrial Revolution (4IR) is impacting engineering education (EE) in diverse with several changes from the effects of the previous three industrial revolutions. Remarkable industrialization has been recorded in the fourth industrial revolution. However, certain skill gaps has been identified missing in engineering courses and curriculum as employers seek skills development aligned with the fourth industrial revolution (4IR). This paper was guided by Lifelong Learning Theory which explain that the paradigm shift from the first three industrial revolutions to 4IR has led to EE transformation of acquiring not only technical skills but also soft skills. This has led to critical EE curriculum review to extrapolate its impacts of soft skills on 4IR emerging workforce. This paper takes a broad look at the EE and soft skills in the era of 4IR in Africa, while examining the EE in previous revolutions and, exploring the impacts and implications of soft skills on EE. The possibilities of adequate investments in EE and soft skills programmes becomes an imperative to address skill gaps and prepare engineering graduate students for future work. The importance of soft skills, values, and improvement of soft skills in engineering education in 4IR era are discussed among others. Thus, to address soft skills gaps in EE, industrial cooperation and educational partnership is significant to centre on EE curriculum future-oriented skills development to consolidate with 4IR workforce demands. A number of policy recommendations for 4IR compatibility with EE polices are made.*

***Key words:** Africa, Curriculum, Engineering education, Soft skills, Lifelong*

I. INTRODUCTION

In the 21st century, Engineering education (EE) has been transformed from the conventional specific branch of learning and curriculum to a comprehensive introductory knowledge or skill acquired for lifelong learning. Thus, Engineering domain by its description, requires practitioners to engage in essential acquisition of knowledge or skill long after formal education completion (Tonso, 2014; Mourtos, 2015; Peters, 2017). Several studies have documented that knowledge and soft skills in high-tech industries will stemmed from EE in the 4th Industrial Revolution (4IR) era, illustrating significant remarkable changes in relation to social and industrial modernization processes (Knobbs and Grayson, 2012; Reaves, 2019). These changes have brought about innovative developmental trends of modern Engineering education in higher learning institutions globally (Naji, Ebead, Al-Ali and Du, 2020). Thus far, Engineering education has become the utmost subject matter of extremely exciting debate vis-à-vis the curriculum structure, high-tech advancement and its enterprise.

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This is determined by several factors, including its keenness and enclosure, teaching and research assessments, philosophical prospectus appraisal, and related impact of status on increased insight of EE core objectives modification (Atman, Sheppard, Turns, Adams, Fleming, Stevens, Streveler, Smith, Miller, Leifer, Yasuhara and Lund, 2010; Brunhaver, 2015). However, individuals' progressions have undergone three industrial revolutions namely: the first industrial revolution (mechanization), the second industrial revolution (mass production and electricity), and the third industrial revolution (automation) (Schwab, 2016; Reaves, 2019). These revolutions do not only influence invention and professional models but also affect the skills required by future workforces in various industries. Significantly, various jobs were substituted with high-tech automation as industrial revolution transition occur (Litchfield, Javernick-Will and Maul, 2016; Peters, 2017). More importantly, some skills turn out to be superfluous, in contrast, others became valuable in engineering firms. The 4IR is no exception in connection with jobs and skills replacement, described by major hi-tech innovation, which requires skilled workforce and experts. The skilled workforce is driving the world into a global, automated, virtual, and flexible setting, result in global jobs contest demanding for specialized skills for digital and economic distribution (WEF, 2015a; 2015b; 2017b). Obvious changes in skill requirements in the fourth industrial revolution and the preceding three industrial revolutions were inevitable (Litchfield et al. 2016). These changes have resulted in assertion of new engineering job requirements aimed at exceptional and specialized soft skills clique. The availability, applicability and proficiencies of soft skills essential in a nation's labour force is deeply rooted on the type and quality of EE aligned with 4IR requirements worldwide (Brunhaver, Korte, Lande and Sheppard, 2010; BHEF, 2011; Carrico, Winters, Brunhaver and Matusovich, 2012). Hence, after acquiring formal education, quality of soft skills and workforce qualifications will be conspicuous in driving its innovation and competiveness in engineering firms. Dearth of requisite soft skills will ensue an evident decline in performance and lower competiveness in labour force groups. This becomes necessary to prioritize human resource development in EE and soft skills, as it revolves round EE prospective development and required soft skills (Brunhaver et al. 2010; Ra, Shrestha, Khatiwada and Yoon, 2019). The transformation of EE and soft skills from the paradigm shift from the first three industrial revolutions to 4IR, has paved way for engineering educational curriculum review. Such that the impacts of 4IR emerging technology will require a new curriculum accreditation that will improve well-informed and ethical cognitive acquisition (Ra, et al. 2019).

This will go a long way to show a great deal of knowledge in connection with socio-cultural impact on EE and soft skills. This will not only increase material opulence but to integrate its social and cultural resources.

For instance, various emerging liberal institutions in developed countries such as the United States and parts of Asia, have implemented new types of EE and soft skills that matches with 4IR model of EE (Shvetsova and Kuzmina, 2018; Ra, et al. 2019). This becomes a necessity as it adapts and scales up new forms of tutelage that will harness the dividends and relevance of EE in the era of 4IR. Nevertheless, these new forms of EE will prepare both students and faculty for leadership roles in a rapid and accelerated change that aligns with the universal curriculum made up of both technical mastery of EE and soft skills training tools (Sackey and Bester, 2016; Pradhan and Agwa-Ejon, 2018). This paper draws mainly from sociology of education, engineering education and human resources as well as economics literature to describe the role of EE together with soft skills in the era of 4IR. It uses secondary sources and examples to explore recommendations. Specifically, the paper explored how soft skills are vital in this present era of the 4IR and how soft skills can improve on the value of EE and engineer practitioners as well as its implications in the 21st century in Africa.

II. LITERATURE REVIEW

2.1 Overview of Engineering Education and soft skills in the 4IR era

During post-world wars period, EE started and advanced from its earliest formal experiences during the 18th century in France. However, in the 21st century which prompted a re-examination of engineer roles to match up skill gaps in fourth industrial revolution society (Martins, Duarte, Cunha, Almada-Lobo, Marques and Magalhaes, 2007; Fomunyam, 2019). Evidently, engineering should go beyond unalloyed technology, which is based on solid scientific and technological knowledge but rather integration of both skills will assist engineers in taking their roles in the industries. However, several programmes have been propelled to develop soft skills for individuals who opt for EE. Such training-based learning programs were built to focus on solving large-scale complex and social problems with the use of soft skill platforms (Martins, et al. 2007; Schwab, 2016). This was then implemented in the new EE curriculum by reaching a balance between soft skills and its course contents for engineering educational programmes. Previous EE curriculum was based on projects and experiences of older engineering industries as well as research knowledge gathered from faculty (Knobbs and Grayson, 2012; Reaves, 2019).

The 4IR industries demands not only quantity but quality engineers equipped with hard and soft skills to solve complex technical challenges, working in interdisciplinary teams and handling socio-cultural concerns as well. In Africa, several efforts have been made to incorporate soft skills in EE in order to address skill gaps in higher learning (WEF, 2016; 2017a). However, in Africa, few successes on the implementation of soft skills in EE higher learning institutions has been reported in several studies (Hoit, Sawicki and Sloan, 2010; Kechagias, 2011). For instance, in the University of Pretoria, South Africa (WEF, 2015a; 2015b; 2016; 2017a; 2017b), soft skills was integrated alongside other non-technical skills in the context of a discipline-specific module were both effective and desirable as well as the mastery of the technical component, far from having to be compromised, was enhanced. Another cited illustration was the Department of Electrical and Computer Engineering, Lafayette College USA, included soft skills into their EE accreditation general criterion student outcome program, followed from their previous curriculum to build future engineers for the 4IR (WEF, 2016; 2017a; 2017b).

Soft skills are critically important for today's engineering programs as higher learning authorities has designated soft skills as non-technical requirements in EE programmes. This was done to build future engineers with 4IR skills. EE in the era of 4IR are presently trained to have a deep and consistent body of scientific knowledge, in several domains, not only in the traditional fields of mathematics and physics, but also in biological, chemical, and life sciences as well as others (Sackey and Bester, 2016). This broad body of scientific knowledge is crucial to multi-disciplinary life-long learning to solve complex problems as real problems usually are. Soft skill training programmes are very key to build entrepreneurial and accountable engineers with deep hard core scientific knowledge to enhance better performances (Atman et al., 2010; Knobbs and Grayson, 2012).

It can be argued that soft skills are vital in virtually every workplace today, regardless of the domain. The role of soft skills in engineering education will go further to enhance abilities to give a 'competitive edge' when seeking employment in 4IR industries. These skills are not just about communicating, but the ability to manage stress, to organize, and to develop team and interpersonal skills (Carnevale, Smith and Melton, 2011; Litchfield, Javernick-Will and Maul, 2016). Importantly, adequate attention has not been geared towards EE while developing technical and non-technical curriculum requirements as soft skills value is often ignored. Thus, the integration of teaching and practice of soft skills in EE is key in the era of 4IR.

2.2 Vital Soft skills in the era of Fourth Industrial Revolution (4IR)

Africa region has stands at a turning point regarding its future development path, having one of the youngest populations, considerably with more educated with much higher productive employment potentials (Akokuwebe and Okunola, 2015; Akokuwebe, Ukpabi and Ejeh, 2017). Thus, the combined effects of rising post-basic educational attainment and large proportion of young people across the region presented sub-Saharan Africa with a unique demographic 'window of opportunity'. The contrast in educational levels of older and younger generations is particularly striking in countries such as Nigeria, Botswana, Benin, Uganda, Malawi and Mozambique (WEF, 2015a; 2015b; Akokuwebe and Okunola, 2015; WEF, 2016). Absence of variations in educational opportunities and investments in line with matched skills development have been a great challenge in the era of Fourth Industrial Revolution (4IR). However, as this era unfolds, African countries are mapping out way forward to develop new innovations with relevant soft skills to boost educational and economic activities (Akokuwebe and Okunola, 2015; Akokuwebe, 2017; Ongbali, Afolalu and Udo, 2019).

For instance, some African countries such as Kenya, Rwanda, South Africa, and Ghana have seized the opportunity in implementing the 4IR policy framework in conforming with modernisation process.

Furthermore, the Fourth Industrial Revolution era is introducing advanced modernized technology, namely: robotics and autonomous transport, artificial and machine learning, advanced materials, biotechnology and genomics (Reaves, 2019). These advancements will go a long way to transform the way individuals live and work. Higher skill requirements will be made mandatory in higher learning as well as in recruitment processes in economic firms, owing to the fact that some jobs will disappear, and other professions will grow as well as non-existent professions in present day will become a common place (Andrews and Higson, 2008). But what is certain is that educational institutions and professions such as Engineers will need to align its expertise to be well-informed with the social and economic changes in the fourth industrial revolution.

Therefore, soft skills that are vital with technology advancement are becoming well-established in EE curriculum and also at the level of professionalism. The rationale for a paradigm shifts in adding soft skills to EE was as a result of skill mismatch in engineering profession, which has fallen behind societal expectations. For instance, five years from now (year 2020), over one-third of skills (35%) that are considered vital in today's workforce would have changed. According to Future of Jobs Reports, as cited by Amador (2020) and Gray (2016), ten soft skills have been referenced to Engineering profession as well as other careers that will thrive in the fourth industrial revolution (4IR) include:

1. **Complex problem solving;** this is a skill that enable an individual to see a link between industries and generate unique and creative solutions to various problems. This skill identifies complex problems, review information related to those problems, and evaluate its options for solutions.
2. **Critical thinking:** this is more concerned with human's ability to turn data into useful interpretations that are interconnected in various fields. Thus, proper critical thinking can lead to better decision-making, career success, well-informed opinions, and improved personal relationships.
3. **Creativity:** This is a process to visualise and turn ideas or visions into reality by properly communicating the outcome of the concepts when it has been executed.
4. **People management:** This is also known as human resource management (HRM), which is centred on recruitment, management, and ongoing support of teamwork as leadership and managerial skills are mandatory for individuals to obtain.
5. **Coordinating with others:** This denotes coordination with others and can be achieved through clear and effective communication, mutual work, team collaboration, and precise expectation settings.
6. **Emotional intelligence (EQ):** This is when an individual's ability to understand and evaluate others. Some individuals have emotional intelligence as a natural talent, while others have to learn it. EQ can be learned through self-awareness, motivation, empathy, social skills, and self-regulation.
7. **Judgement and decision making:** This skill is connected with one's ability to summarize huge amount of data, using data analytics and interpret data that will infer right decision-making. Clear decisions within an organization can lead to tactical and strategic decisions as well as proper planning. The idea of a good decision can lead to a useful action.
8. **Service orientation:** This is built on judgement in decision-making and cognitive process of reaching a decision in drawing out a solution. Therefore, service orientation can be mastered through work with individuals in solving specific real-life situations.
9. **Negotiation:** This is an approach to individual bargain and create a win-win situation. The ability to negotiate in everyday situations is key and this is highly needed in modern industries.
10. **Cognitive flexibility:** This skill is about the brain's ability to transit or switch from one dimension to another. This way, individuals can expand their level of cognitive flexibility at different personal levels to meet various challenges at hand.

III. VALUE AND IMPROVEMENT OF SOFT SKILLS IN ENGINEERING EDUCATION IN THE 21ST CENTURY

Education is key to human rights, a central part of human and professional development which is an essential prerequisite for solving complex problems and improvement in workforce. It can be developed through experience acquired and skills learnt which provide intellectual development for engineering profession. Thus, EE plays a fundamental role in the development, sustenance of economic growth and promotion of society's welfare (Abdulwahed and Hasna, 2017). This begins with a careful preparation of human capital to meet up with the 4IR opportunities and challenges in the 21st century. It is important to know that engineering and related STEM disciplines (Science, Technology, Engineering and Mathematics) are involved in continuous process of modernization and revolution (BHEF, 2011; Carnevale et al., 2011). This will provide better opportunities to serve the society and addresses social issues at the grassroots' level.

However, the present competitive global market and changing work environment, are highly demanding as engineers are mandated to possess soft skills in addition to technical skills acquired. This will assist engineers to fathom project goals, with ability to complete them with available resources (Litchfield et al., 2016). In order to meet the demands of 4IR, engineering programs are challenged to create innovative techniques to teach classes so that graduate students are prepared to take on the challenges in this present era. Today's workforce obliges well-educated engineers with variety of skills to efficiently elucidate difficulties and improve university curriculum. Also, engineering profession demands effective range of soft skills with acquired advanced technical skills (Shvetsova et al., 2018). In spite of such needs in the engineering labour force, academic engineering curriculum are developed to focus on technical skills, neglecting important 4IR soft skills.

Effective development of soft skills in engineering education will aid future engineers in engaging interdisciplinary endeavours. This will bring positive edification in formulating economic policies for burgeoning technologies.

The fourth industrial revolution century has transformed teaching and learning that is rebranded by rapid technological advancements. In present day, engineering profession is driven by information, knowledge, and innovation which requires technical and soft skills development (Forbes, Bielefeldt and Sullivan, 2015). Existing studies have indicated theoretical models are not adequate in supporting engineering students in problem solving; and having only technical skills is no longer satisfactory for employers in highly competitive labour force in the 21st century (Andrews and Higson, 2008; Hoit, Sawicki and Sloan, 2010; Abdulwahed and Hasna, 2017). The transformation of the fourth industrial revolution has brought changes that have resulted to increased demand for soft skills. The need for individual soft skills has taken prominence as most employers will go for employees with both technical and soft skills development (Sackey and Bester, 2016).

Due to lack or mismatch of skill development, low labour costs and offset by new job creation in addition to job disruption is a serious concern in Africa, regardless of African population being seen as a ‘window of opportunity’. For instance, in South Africa 41% of all work activities are vulnerable to robotics, as are 44% in Ethiopia, and 46% in Nigeria as well as 52% in Kenya (Kirk, 2010; WEF, 2016; 2017a; Ongbali et al., 2019). Similarly, a major identified constraint to businesses across some African countries include inadequate skilled workforces. This was established in Tanzania (41% of all firms), Kenya (30%), South Africa (9%) and Nigeria (6%) (Kirk, 2010; WEF, 2016; 2017a; Ongbali et al., 2019). This pattern of inadequate skill projections may get worse in the future if it is not properly addressed and becomes nation’s priority agenda. Other instances in South Africa alone revealed about 39% of core skills required across occupations will be solely not the same by 2020 (Kirk, 2010; WEF, 2016; 2017a). Besides, skills instability often stems from the information that many jobs in Africa are becoming more intense with the use of soft skills and digital technologies. In the longer span, strong EE potentials are incorporated with soft skills learning facilities that will prepare future employees for industries growth and successful job recruitment.

Although, education for engineering students starts at the higher learning institutions, the seed for producing a competent engineering professional must be sowed in basic engineering classes with technical and soft skills (Sackey and Bester, 2016; Fomunyam, 2019). Soft skills are rarely discussed in traditional engineering courses, which makes it difficult to produce competent engineering graduates who possess soft skill. In order to produce a competent engineer, engineering students must possess both technical and non-technical soft skills, giving them edge. Furthermore, the National Academy of Engineers (2004) lay emphasis on engineering educators and curriculum developers to look forward to the affected changes in engineering practices, by adapting skills development programmes for training engineering students. This will go a long way to sustain expertise that will keep up with economic competency and improve national’s quality of life through engineering professions with vital skills development.

IV. THEORETICAL FRAMEWORK

This paper is anchored on lifelong learning theory which was developed from the term “life-long learners”, created by Leslie Watkins and used by Professor Clint Taylor (CSULA) and Superintendent for the Temple City Unified School District’s mission statement in 1993. Lifelong learning theoretical model emphasizes on human development and potential through continuous and supportive process that stimulates and empowers individuals to acquire knowledge, values, and skills required throughout lifetime (Longworth and Davies, 1996; Julia Gross, 2012; Marco Kalz, 2015).

Lifelong learning is associated with soft skill development for engineering students through continuing education and self-directed learning. In the twenty first century, several studies have stressed the importance of lifelong learning in the fourth industrial revolution era, owing to demographics, environmental imperatives, the pervasive access to new technology information, and innovation speed in soft skills assessment in engineering profession (Illeris, 2011; Ra et al., 2019). As a result of these factors, it becomes progressively a necessity not to equip people with hard skills alone but with soft skills and competences to meet up with the exigency of fourth industrial revolution period.

However, barriers to lifelong learning of soft skill development have been identified in previous studies and these can lead to poor teaching and adaptability to the use of soft skills by engineering professionals. These barriers include poor participation and culture of learning, lack of funding to take part in soft skill development programmes, and learning providers not aligned with the needs of learners (Martins et al., 2007; Mejia, Revelo, Villanueva and Mejia, 2018). Other factors may centred on poor information services for inviting people to learning, distance from learning facilities, lack of home facilities for study and poor awareness of advantages of self-development of soft skills (Dameron and Durand, 2013; Gibb, 2014). These factors have shown that there is still gap between the relevance of soft skills development and engineering education. Thus, soft skill development is lifelong learning and should be developed with curriculum aligned with fourth industrial revolution. To fill the skill gaps, educators must build new pedagogical curriculum and instructional methods for engineering education in Africa.

V. DISCUSSION

In recent years, the engineering educational bodies has invested significant drive and resources in creating rigorous empirical knowledge in transforming engineering education practices. As the advocacy for competent engineering professionals is publicized, soft skill training programmes begins to emerge in the fourth industrial revolution era.

Previous studies have ascertained that lack of communication and leadership gotten from formal education are major concerns as it uncovers skill gaps in engineering education (Atman et al., 2010).

For instance, Arciszewski (2006) has drawn attention to skill gaps in civil engineering profession where mechanisms were used to stimulate higher learning faculty to take proper actions focused majorly in skill development. Also, de Riddler et al. (2014) focused on training gap by laying emphasis on soft skills importance and its impact on personal growth. Lately, an awakened rush for soft skills inclusion in curriculums has been advocated for EE. Such that fourth industrial revolution industries evaluate engineering graduates differently, by focusing on both hard and soft skills. This evaluation was done to separate applicants with both skills development from those who do not have. Thus, there are many reasons as to why engineering education is lacking soft skills development. One of the major reasons is that engineering research has been tied to the same wave of curriculum, with little or no input from industrial sector (Sackey and Bester, 2016). This has raised questions based on objections as to why soft skills courses are not included in the modern engineering curriculum. But this could be attributed to the premise that with engineering students being taught, hypothetically they could develop soft skills for themselves. This assumed thought has made many engineering students to acquire more technical skills related competence compared with soft skills development and prompt employers to review stringent employability process (Martins et al., 2007; Ongbali et al., 2019).
A paradigm shift in curriculum revision with soft skills inclusion will add value to engineering profession and its workforce. The need to provide engineering students with enhanced professional skills combined with incipient core skill prerequisite, may appear as a frightening proposition for older engineering educators (Mourtos, 2015). As the previous engineering curriculum is firmly defined by outdated course content and in general, have few resources and little time for revising or incorporating new knowledge. Engineering enrollments are increasing during school admission, thereby putting more demands on faculty and institutional resources. Thus far, it is interesting to note that engineering students can upgrade their skills development through formal and informal means, including online or in-person settings. The formal standard for engineering graduates to upgrade their skill development is by obtaining credentials such as professional certifications, licenses, and educational certificates (Peters, 2017). Similarly, perception towards learning a skill is key and it may hinder one’s desire or make effort to acquire the skill. Perception could alter performance and outcome, such that positively altered perception towards learning soft skills will be inclined to putting more time and effort. Engineering education has a strong element of perception where the efforts put into acquiring skills will depend on one’s insight towards the benefits of such skill (Martins et al., 2007; Carrico et al., 2012). For instance, investing in engineering education is the best approach to address skill gaps and poor training for engineering students. But if the engineering students have poor perception towards acquiring these skills, such investments become unproductive. Preparing individuals with positive perception can meaningfully enhance the role of acquiring soft skills and making use of them in future endeavours (Tracey and Sodano, 2013). Engineering skills, knowledge and perception are foundational to technological innovation and development that drives economic growth and solve societal issues in future.
Moreover, recently engineering schools are considering incorporating sustainability, societal impact, and public policy in the curriculum, which need seeking inputs and effective communication between educational institutions and diverse industries. Demands from employers for engineering graduates who have acquired strong professional skills appears to be intensified along with central role played and expectations from past learning institutions (Brunhaver et al., 2010; Forbes et al., 2015). In addition to traditional skills such as oral and written communication along with teamwork, the fourth industrial revolution employers are looking for engineers that have soft skills such as creativity, leadership, entrepreneurial skills, lifelong learning skills, and ability to participate in interdisciplinary research capacity. Engineering educators, ABET, incorporated as the Accreditation Board for Engineering and Technology, Inc., and engineering Organisational bodies are acting on the workplace demands of soft skills in 4IR era (Carrico, 2012). Nevertheless, the concerns persist in part, as a result of the processes for soft skills development in engineering labour force remains largely unplanned especially in African institutions of higher learning. Therefore, efforts to implement and access soft skills training programmes and tools can be strengthened with more exploration into several mechanisms that will extend engineering education beyond technical education. This will advocate engineering educational curriculum review, which will in itself enhance personal development, and participation in learning as well as assessment of soft skills curriculum in engineering schools.

VI. CONCLUSION AND RECOMMENDATIONS

Engineering education is changing with response to rapid technological change, increasing globalization, and more diverse engineering student populations. The need to address skill gaps is to incorporate new skills from the 4IR platforms, which will build engineering students for better performance at the workplace in the near future. Although, an attached link between technical and soft skills has been cited in existing studies, yet there is still gap in soft skill development in engineering education in Africa. Thus, there is need to refocus on the quality and improvement of EE and also the expansion of insightful engineering programmes should centred on planning and labour market assessment in 4IR era. Adequate funding of skill development training programmes and sustaining engineering education has a significant social and economic implication for policies and multinational corporations. Therefore, we identified the following practical and effective recommendations in addressing soft skill gaps in engineering education in Africa:

1. ensuring engineering teachers to have deep-rooted knowledge of engineering discipline as well as adequate support for professional skills development by having access to high-quality learning opportunities.

2. to invest more in engineering education by providing technical and soft skills instructional training and revised curriculum to align with fourth industrial revolution era.
3. promoting skill development training participation for both engineering educators and students to enable them gain skills to recognize such training participation can build them for better collaboration and employability in future workforce.
4. provide engineering education with 21st century and accurate information about engineering profession as this will prepare future engineering graduates to navigate their education and enter workforce without issues.
5. help engineering students to understand the utility and rewards of self-development through skills training programmes in order to earn an engineering degree and career in high resourcefulness for research collaboration between higher institutional learning and industries.

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