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Active Role of Learning Institutions in Promoting Fourth Industrial Revolution (4IR)

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Abstract*—Industrial revolution has gone through four phases denoted as the 1st industrial revolution (industry 1.0) through the 4th industrial revolution (4IR or industry 4.0). The 4th industrial revolution is taking place in the digital and knowledge based economy. The major enablers of 4IR are integrated technologies that include Internet of Things (IoT), Cyber Physical Systems (CPS), and Cloud Computing (CC). University campuses and other learning institutions play an important role in promoting creativity and innovation among student and professional communities. Such efforts range from boot camps to winter school programs. They promote rapid catching up with fast-changing technology, in collaborative, unique and inspiring environments. Extra curricula activities administered to multi-disciplinary groups are more effective compared to traditional individual centered assignments. The article looks at the role that the Botswana International University of Science and Technology (BIUST) plays in creating an environment conducive to promote 4IR. A qualitative approach is used to study the engineering education initiatives since the inception of the university. Currently BIUST uses the winter school model for enrolled engineering students. The program allows second year students to undergo various engineering workshop practices, gaining essential hands-on skills. The BIUST engineering workshop houses more than twenty laboratories. In order to promote 4IR, the laboratories are equipped with state-of-the-arts machinery for thermal processes, advanced manufacturing, meteorology, and many other disciplines. Other initiatives being mooted to promote 4IR are targeted infrastructure, skills development, financing models, and promoting partnerships between public and private sector (3Ps) through MOUs.

Keywords: : Fourth Industrial Revolution, 4IR, Industry 4.0, Technology Transfer, Innovation, Engineering Education, Active Learning

I. Introduction

The term Fourth Industrial Revolution (4IR), also known as Industry 4.0, was pioneered in Germany [1-2]. Industry 4.0 refers to the fourth industrial revolution. The 4IR calls for a dynamic transformation of how all aspects of business and production are done. As 4IR continues to change the world, new challenges arise. Successful implementation of the 4IR requires a new digital culture, training, clear vision, support the executives and management, and investment in digital technologies. Organisations must recruit and developing new talent, and be prepared to change [3-4].

The 4IR brings a paradigm shift in education. New trends drift towards less standardised and more personalised (education anywhere and anytime), with particular emphasis on creativity, collaboration, knowledge production and sharing, complex problem solving, flexibility, innovation, adaptiveness, resilience, and leadership skills [5-7]. Citizens of the 4IR need to possess vital and urgent basic and transversal digital literacy skills in order to live, share, communicate, work, learn and actively participate in the 4IR era. The 4IR era is characterized by speed, complexity, hyper-connected and increasingly knowledge-based society. Digital literacy skills for the 4IR include information literacy skills, media literacy skills, and Information and Communication Technologies (ICT) literacy skills.

Under the 4IR, business and industry takes a global focus. Advanced technologies makes globalization a reality since all supply chains can be visible across the world. Connectivity brings agility and visibility in all phases of business execution. Every country and every national becomes a global citizen, actively participating in the global economy. This broad scope of participation requires critical thinking and problem solving skills. The education system of the 4IR must nature global citizens with requisite attributes and abilities. There should be no boundaries in skills and participation.

II. Redesigning Engineering Education

A. Fourth Industrial Revolution

Industrial development has gone through four (4) revolutions in historic times. Shwab [8] gives an illustration to help understand how the industrial revolutions changed across time. During the 1st IR, water and steam were used to mechanize production. During the 2nd IR, electric power was used to create mass production. During the 3rd IR, electronics and information technology were used to automate production [9]. The humankind has been at the center stage of evolving the technology and resources used to make products. Necessity is the push factor that stretches the human mind to

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become innovative. As highlighted in the introduction, humankind cannot endure discomfort indefinitely. In times of need for better production means, advanced machinery is launched, whilst a threatening scarcity triggers optimization or substitution of resources. The phases of industrial revolution are denoted as 1st industrial revolution (industry 1.0) through 4th industrial revolution (4IR).

The current level of industrial revolution, industry 4.0, is anchored on integrated technologies that include Internet of Things (IoT), Cyber Physical Systems (CPS), and Cloud Computing (CC) [10 - 12]. Cyber-physical systems (CPS) are physical and engineered systems, whose operations are monitored, coordinated, controlled and integrated by a computing and communication core [13]. CPS can be considered to be a confluence of embedded systems, real-time systems, distributed sensor systems and controls. CPS-enabled smart factories have a network of intelligent objects linking products and assets with information from the internet, as well as capturing context information. Many factors contribute to the progression of manufacturing trends through to the current phase (industry 4.0) and beyond. Some of them include shorter product life cycles, increasing product variation (mass customization), volatile markets, cost reduction pressures, scarce resources, cleaner production, lack of skilled workforce and aging community [14]. Cyber Physical Systems (CPS) and Internet of Things (IoT) technologies such as RFID, wired and wireless sensor networks, and embedded systems enable the digitization and virtualization of shared resources and capabilities in the services, manufacturing and supply chain management for access through the cloud resource pool. These technologies extend the internet into the real world, embracing everyday objects. Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [15]. Individuals and corporate end users access the cloud through internet and access spans over different enterprises and platforms. Cloud services are based on technologies such as HTTP, HTML, XML, JavaScript, or other protocols. CC makes it possible to deliver enterprise information systems (EISs) where each party can contribute to the establishment of the advanced system, while delivering superior integration capabilities with any party's legacy systems and web-based intranets applications.

The 4IR requires the world to produce a new kind of worker—a knowledge worker. Industry leaders, managers and workers must possess skill sets to adapt, to manage their operations in the 4IR. Critical thinking, problem solving, innovation, and communication are some crucial skills required under the 4IR. Change does not wait for anyone. Business, educators, and governments must be innovative in training and retraining the 4IR compliant workforce. Without appropriate models, the future will lack an ill-prepared generation and incapable workforce.

B. Marker Spaces

Makerspaces are being embraced in the education sector as an important development for engineering design education. University campuses and other training institutions are phasing out traditional machine shops, combining the traditional equipment with digital design and manufacturing tools to establish creative communities [16]. Educational makerspace communities support academic, extracurricular and personal design activities under the watch of schools, university faculties, staff, and students. Although makerspaces generally fall under one umbrella definition, different institutions craft out unique focus that drives the identity of the institutions. Various initiatives have been pioneered to promote creativity and innovation among student and professional communities. Such efforts range from boot camps to winter school programs. They promote rapid catching up with fast-changing technology, in collaborative, unique and inspiring environments. Unlike the formal education curricula which contributed to official assessments, these activities are extra curricula and administered to multi-disciplinary groups who are self-motivated to go an extra mile. The approach generates a significant multiplier effect where more interested individuals continue to join the movement.

Engineering education curriculum is centred on solving societal problems by using proven science to design products and systems. Because of the ever-growing complexity of the modern world, design is gaining more attention. Makerspaces are more useful in promoting engineering design because they shorten the time taken to launch new ideas into physical designs. They support iteration of ideas until better solutions are achieved. The culture of the maker movement promotes hands-on learning, openness to new ideas, diversity within problem-solving teams, sharing of techniques and results, teamwork, and multi-disciplinary approach. People use makerspaces for socializing and learning. Individuals with diverse backgrounds and skills come together, self-organize according to their needs and take decisions collectively on issues that appear throughout a project's life (Moilanen, 2012). Through activities such as workshops, software and hardware development, prototyping of new products and processes or improvement of existing ones; the overall aim is to facilitate collective discovery and experimentation, enabling the community to participate actively by peer to peer learning and horizontal knowledge exchange [17].

C. Learning Factories

Engineering education curriculum is centered on solving societal problems by using proven science to design products and systems. Because of the ever-growing complexity of the modern world, design is gaining more attention [18 - 20]. University campuses and other training institutions are

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phasing out traditional machine shops, combining the traditional equipment with digital design and manufacturing tools to establish creative communities [21]. Various initiatives have been pioneered to promote creativity and innovation among student and professional communities. Such efforts range from boot camps to winter school programs. They promote rapid catching up with fast-changing technology, in collaborative, unique and inspiring environments. Unlike the formal education curricula which contributed to official assessments, these activities are extra curricula and administered to multi-disciplinary groups who are self-motivated to go an extra mile. The approach generates a significant multiplier effect where more interested individuals collaborate.

A learning factory (LF) is an idealized replica of the real world value chain industry that supports formal and informal learning through interdisciplinary hands-on engineering design projects with strong links and interactions with industry [22-23]. The LF concept was pioneered by a group of universities from the United States in 1995, led by Penn State University [24, 25]. Later on the European government and other states adopted the LF initiative to enhance education of engineers. LFs bring the real world into engineering education. Engineering graduates are exposed to the real life product life cycle – conception, design, prototyping, manufacturing and distribution. LF facilities consist of modern manufacturing facilities – CAD/CAM, CNC and manual machine centers, 3D printing, welding, and metrology.

D. *Education 4.0*

The fourth Industrial Revolution (4IR) has broad impacts on education. New skills demanded by the 4IR workforce pushes the education sector to innovate and become ready to produce required expertise. 4IR is controlled by artificial intelligence and digital physical frameworks that make human-machine interface more universal. Quick revolution in innovation has delivered another model of education for the future – Education 4.0 [26]. The new vision of learning promotes learners to learn not only skills and knowledge that are needed but also to identify the source to learn these skills and knowledge (Fisk, 2017). In education 4.0, teachers assume the role of facilitators and tracking of learners' performance is done through data-based customization. The new future of education promises a system that:

- responds to the needs of "industry 4.0" or the fourth industrial revolution, where man and machine align to enable new possibilities,
- harnesses the potential of digital technologies, personalised data, open sourced content, and the new humanity of this globally-connected, technology-fueled world,
- establishes a blueprint for the future of learning – lifelong learning – from childhood schooling, to continuous learning in the workplace, to learning to play a better role in society.

Some initiatives of Education 4.0 include Active Blended Learning (ABL). ABL provides a learning environment for students to play an active role. Students are given an opportunity to engage in a variety of ways in and outside the classroom, in the field, in the lab, in the studio and in the workplace.

Chatbots can also be used to help students. Other initiatives in higher education include exchange of students and staff, which is enabled through global and regional networks, and consortium of higher education institutions. Curriculum delivery and technology transfer also make the communities be mindful of the benefits and risks brought about by the 4th Industrial Revolution [27].

III. Practical Engineering Skills Training at BIUST

A. *Winter School Prgramme*

Winter school and Summer school are educational programmes that offer a range of short courses to boost practical competences among students. These extra curricula programmes are run outside the main academic calendar. Other institutions make use of boot camps to achieve similar purposes. BIUST has been running the winter school programme since its inception. The winter school is offered to engineering students.

B. *Enrollment Statistics*

BIUST has an annual enrollment of at least 100 students in the Faculty of Engineering and Technology (FET). Upon inception, the university was offering eleven (11) engineering programmes. However, some of the programmes have since been merged due to a number of constraints. The year 2016 had the highest number of students (four hundred and six – 406) who participated in the winter school. The group has was very large and presented several challenges to the institution in terms of efficient teaching. As a young institution, infrastructure is not yet adequate to handle large numbers. There is also a challenge of sustainable student-teacher ratios. These lessons contributed to a new resolution to limit enrollment to 25 students per programme. Fig 1 shows the enrollment statistics.

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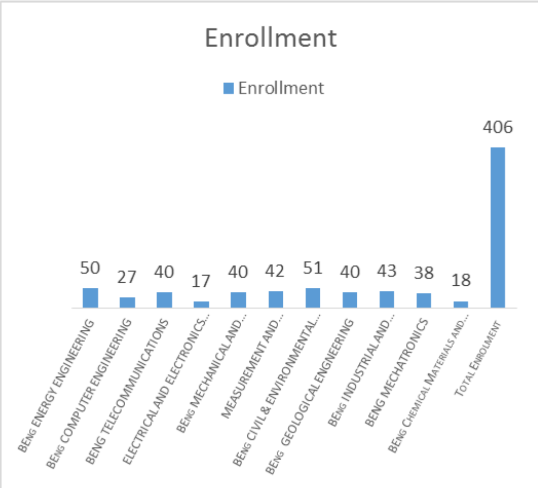

Fig. 1. Winter school enrollment for 2016

The winter school exposes students to a number of practical engineering skills. These range from the use of software programmes for engineering design, modeling, analysis, to workshop practice in fabrication, and other electrical-electronic engineering skills. BIUST has a number of engineering labs equipped with states of the arts software and industrial scale machines for imparting relevant engineering skills to students. Industrial scale machines include CNC lathes, CNC laser cutting, CNC plasma cutting, Water jet cutting, Flexible manufacturing center equipped with a robot. The labs are not only used for learning purposes, but are also used to carry out private jobs from industry. Fig 2 shows the distribution of students who enrolled in specific short courses during the year 2016 winter school programme.

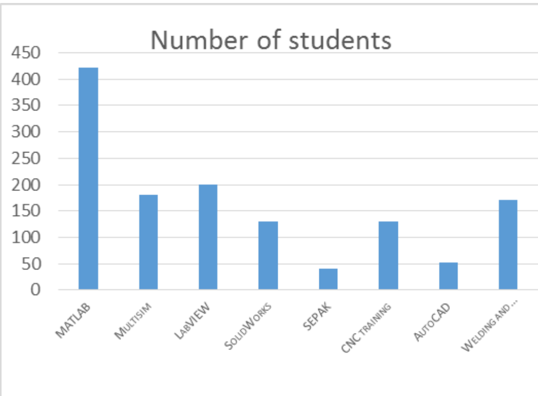

Fig. 2. Number of students who enrolled in specific courses in 2016

IV. Conclusion

The fourth industrial revolution (4IR) is changing the world. Components of the 4IR - Artificial intelligence (AI), robotics, big data, internet of things (IoT), and Cloud Computing (CC) impacts on jobs and industry. The workforce of the 4IR perform intellectually intensive jobs which require innovative training through cross cutting education models. Education initiatives to bridge the gap between expectations of the 4IR and current practice include winter school programmes, boot camps, staff and student exchanges, industry-academia linkages, and academics attachment in industry. Full utilization of advanced technologies brought through the 4IR converges to an Education 4.0 experience. Students can only be better prepared for the 4IR jobs when they are exposed to industry technology in the classroom. Technology is changing fast and old education models where students experience real work after finishing four-five year programmes is no longer effective.

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