Effective Application of 4th Industrial Revolution Technologies During Engineering Research and Teaching in Ugandan Universities

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Abstract: The 4th Industrial Revolution (4IR) technologies is the recent research topic of interest among the academicians, since the 4IR technologies make up the latest era of digitization. The 4IR technologies demands changes in the three fundamental functions (teaching, research and community service) of higher institutions of learning. Each revolution technologies needs different job skills and competences, the 4IR technologies will also require new job skills and competences from the university graduates particularly in the field of engineering. The teaching staff at universities shall play an important role in imparting the necessary job skills and competences to graduates. Recently several research on 4IR technologies in higher institutions of learning has been presented, but none is addressing the issue of availability of effective utilization of 4IR technologies in engineering education. So, this paper presents the investigation of the availability of effective application of 4IR technologies during university engineering research and teaching in Ugandan universities. The paper also examined the behavior, knowledge, and perception of teaching staff towards 4IR technologies in the university engineering education in Uganda. 256 respondents were interviewed using online questionnaire and data collected was analyzed using MATLAB program. The findings disclose that there is low degree of application of 4IR technologies by teaching staff in engineering sector during teaching and research in the seven universities in Uganda.

Keywords: 4th Industrial Revolution Technologies; Application; Knowledge; Perception; Teaching, Research; Community Service; Education; Engineering, Teaching Staff, Academicians

1. Introduction

According to literature, human civilization has gone through three stages of industrial revolutions namely; 1st Industrial Revolution (Power of steam and water dramatically increased the productivity of human labor); 2nd Industrial Revolution (Mass industrial production; Electricity as the key driver); 3rd Industrial Revolution (Information technology; the use of computing in industry and the development of personal computers) [1 -2]. Of recent 3rd Industrial Revolution has evolved into 4th Industrial Revolution (4IR). The 4IR is characterized by the joining of the digital, biological, and physical worlds, as well as the new technologies such as block chain, robotics, Artificial Intelligence (AI), Big Data, Internet of Things (IoT), automation, data exchanges, cyber – physical systems, cloud computing, semi-autonomous industrial techniques, 5G Network and among others. Generally, 4IR represent the movement towards to the smart industry and industrial goals. Those revolutions affect production, business models, management and human resources [3]. From one revolution to the next, some job skills cease to be of relevant and others are created.

The evolution of 4IR technologies has attracted academicians' attention particularly in the field of engineering. Regardless of the era, the universities are expected to produce graduates that shall work and deal with more and more automated, globalized, networked, virtualized and flexible world [4]. The graduates shall compete for employment on the global market. In this way, new skills and competences will become very crucial [5]. The university teaching staff shall play a major role in imparting the necessary skills and competences to the graduates by ensuring quality learning through teaching, enabling the students to get the latest knowledge via exploratory research, and sustaining the development of societies by means of service.

Recently several research on 4IR technologies in higher institutions of learning has been presented in [6-10], on Forums like World Economic Forum and so on, but none is addressing the issue of availability of effective utilization of 4IR technologies in engineering education. This paper presents the investigation of the availability of effective application of 4IR technologies during university engineering research and teaching in

the seven universities in Uganda. The paper also examined the behavior, knowledge, and perception of teaching staff towards 4IR technologies in university engineering education.

2. Materials and Methods

In [11], using a questionnaire as a survey tool among academicians has proved to be an ideal method in exploring individuals' behavior, knowledge, perceptions and thoughts. Hence, this research employed quantitative approach, whereby the data were collected through an online questionnaire presented in Table 1.

Table 1: The Online Survey Questionnaire

#	Question's text	Kind of Answers
Qn. 1	Sex /Gender	Male or Female
	Behavior	
Qn. 2	Which of the following devices do you own? GPU; Laptop or Computer; Smartphone; Digital Camera; Webcam; Tablet; Pad; Vision sensor; others…?	Indicate one or more devices or other…
Qn. 3	Which of the following activities do you perform regularly? Using GPU; Programming in Python and MATLAB; Developing AI and machine learning algorithms; Developing robotics and intelligent systems; 3D printing; Read and download images and documents from the web; Use collaborative and sharing applications; Do web research; Developing smart homes, healthcare and agricultural system; Giving online lectures; others…?	Indicate one or more options or other…
Qn. 4	What do you think is the level of importance attributed to the ability to interact with the students, even during lectures and research, through the use of personal digital devices?	Not Important; Uncertain; Important; Very Important
	Knowledge	
Qn. 5	Have you ever heard about 4IR technologies (AI; Robotics; Block Chain; IoT; 3D printing; Rapid Prototyping; Cloud Computing; Cyber Security Systems; automation; Big Data; Data Exchangers; Semi – autonomous industry techniques etc.)?	Yes; often; Seldom; Very rarely; Never
Qn. 6	How wide spread is 4IR technologies in your current curriculum/ courses offered?	Not widely; Uncertain; Widely
Qn. 7	How adaptable are you for 4IR technologies in teaching and research?	Not Ready; Uncertain; Ready; Very Ready
	Applications and Perception	
Qn. 8	How often do you apply 4IR technologies in teaching or lecturing?	More often; Often; Very rarely; Never
Qn. 9	How often do you apply 4IR techniques in your research?	More often; Often; Very rarely; Never
Qn. 10	How relevant is 4IR technologies in your research and teaching?	Not Important; Uncertain; Important; Very Important
Qn. 11	What do you think is the level of importance attributed to the ability of use augmented 4IR technologies in engineering research and teaching?	Not Important; Uncertain; Important; Very Important

The respondents were academicians who are teaching engineering courses in the following universities in Uganda; Busitema University, International University of East Africa, Kampala International University, Kyambogo University, Makerere University, Mbarara University of Science and Technology, and Muteesa I Royal University. Each consent was obtained by contacting the participant via email, then followed an interview notification by the same means.

The main aim of the survey was to check if there is effective application of 4IR technologies by academicians during engineering research and teaching in the seven universities in Uganda. In addition to collecting their opinions on the behavior, knowledge, and perception towards to 4IR technologies in the university engineering education.

The data collected were analyzed using MATLAB program, then the results are presented and discussed in details, and finally the conclusion was drawn.

3. Results and Discussions

3.1 Questionnaire demographics and participation

The questionnaire, as aforementioned, was used to conduct the survey. It was administered to the teaching staff handling engineering programs (Mechanical, Civil, Electrical, Agricultural, Biological, Biomedical, Environmental, Industrial, Computer and so on) in the seven universities in Uganda.

The number of academicians that participated to the survey are 256, 92.3% (238) were male and rest being female 7.7% (18) as presented in Table 1 and Fig.1.

Table 2: Academicians' Sample Size

	Academicians Participated in the Survey	
Sex	**#**	**%**
Male	238	92.3
Female	18	7.7

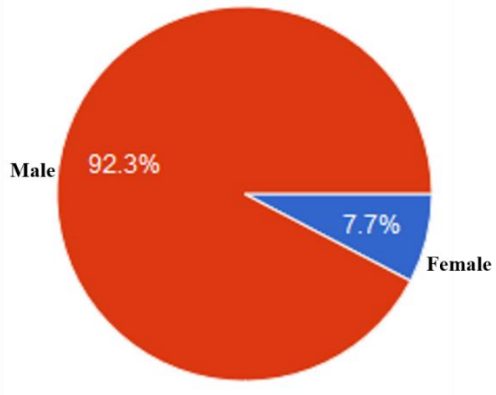


Figure 1: Academicians Sample Size in Percentage

3.2 Questions on Academicians 4IR Technologies Behaviour

Questions Q.2, Qn.3 and Qn. 4 consider the academicians' 4IR technologies behavior. In particular, Qn. 2, is meant to find out whether the teaching staff in the universities possess the tools that are required to delivered 4IR technologies to the students, Qn. 3 investigates the habits of academicians that related to the 4IR technologies in engineering education, Qn. 4, considers the opportunity of the students to directly interact with the academicians by using 4IR technologies tools during teaching and research.

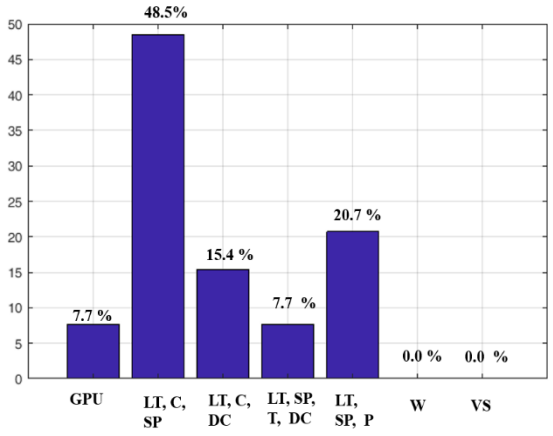
In Qn.1, around 92.3 % of the teaching staff possess the common devices (Laptops, desktop computer, smart phones, digital cameras, pads and so on) and they luck devices which are mostly relevant in the teaching 4IR technologies. These devices are: Graphical Processing Unit (GPU), Vision sensors and Webcam, and in they contribute only 7.7% as depicted in Fig. 2 (a).

Results in Fig. 2(b), shows that the academicians give a lot of their attention on reading and downloading images and documents from web as indicated by 30.6%. Computer programming is also another popular activity among academicians in engineering section, indicated by 30%. 12.4% are not sure whether they perform the listed activities. Less attention is given to activities like: Developing AI and machine learning algorithms; Developing robotics and intelligent systems; 3D printing; Use collaborative and sharing applications; Developing smart homes; Healthcare and Agricultural system; Giving online lectures as they are contributed by low percentage.

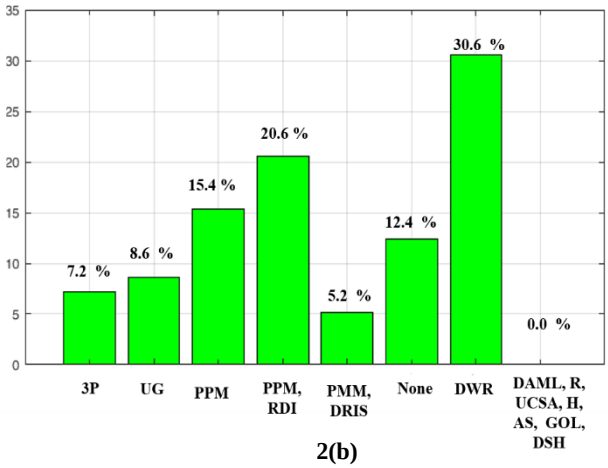
Results in Fig. 2(c), indicate that more of the 46.2 % and 53.8 % of the academicians assumed that the opportunity of student to teaching staff interaction using 4IR technologies during teaching and research seems to be very important and important respectively.

Qn.2 Which of the following devices do you own? GPU; Laptop (LT) or Computer (C); Smartphone (SP); Digital Camera (DC); Webcam (W); Tablet (T); Pad (P); Vision sensor (VS); others…?

Qn.3 Which of the following activities do you perform regularly? Using GPU (UG); Programming in Python and MATLAB (PPM); Developing AI and machine learning algorithms (DAML); Developing robotics and intelligent systems (DRIS); 3D printing (3P); Read and download images and documents from the web (R); Use collaborative and sharing applications (UCSA); Do web research (DWR); Developing smart homes (DSH); Healthcare (H) and Agricultural system (AS); Giving online lectures (GOL); others…?

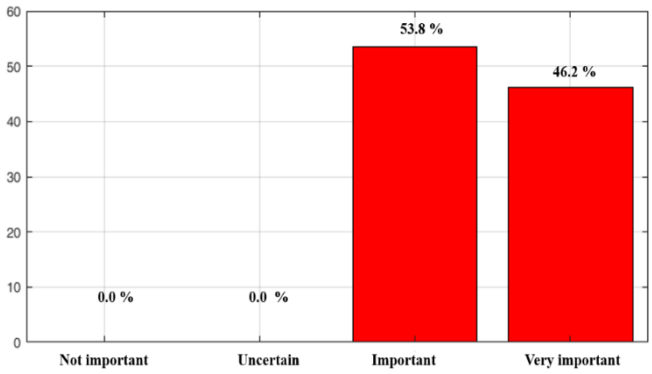


2(a)



2(b)

Qn. 4 What do you think is the level of importance attributed to the ability to interact with the students, even during lectures and research, through the use of personal digital devices?



2(c)

Figure 2: Questions on Academicians 4IR Technologies Behaviour

3.2 Questions on the Academicians' knowledge of 4IR Technologies

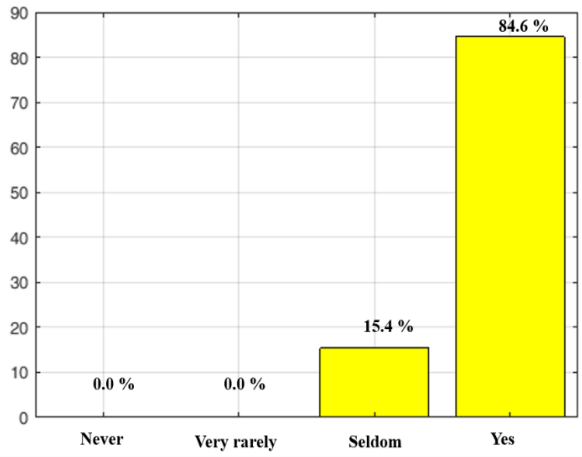
Qn. 4, Qn. 5 and Qn.6, consider the academicians' awareness of 4IR technologies, spread of 4IR technologies in their curriculum, and the degree of readiness to use 4IR technologies in teaching and research.

Results in Fig. 3(a), shows that more than 84% of academicians have ever heard of 4IR technologies. More than 53.8 % of the academicians indicated that 4IR technologies are not widely spread into their current curriculum, 30.8% are not sure and 15.4% indicated widely spread as depicted in Fig. 3(b). In Fig. 3(c), 53.8% of teaching staff are not prepared for 4IR technologies, 7.7% are uncertain, and 37.5% are well prepared.

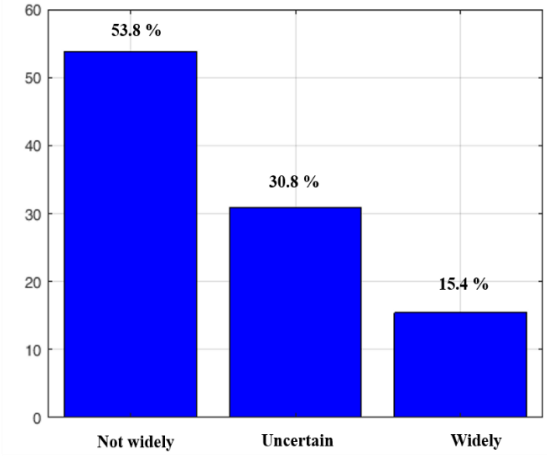
According to the results obtained the teaching staff are aware of 4IR technologies, however the 4IR technologies are not widely spread in their current curriculum and majority of the academicians are not ready to apply 4IR technologies during engineering research and teaching.

Qn. 5 Have you ever heard about 4IR technologies (AI; Robotics; Block Chain; IoT; 3D printing; Rapid Prototyping; Cloud Computing; Cyber Security Systems; automation; Big Data; Data Exchangers; Semi – autonomous industry techniques; 5G Networks etc.)?

Qn. 6 How wide spread is 4IR technologies in your current curriculum / courses offered?

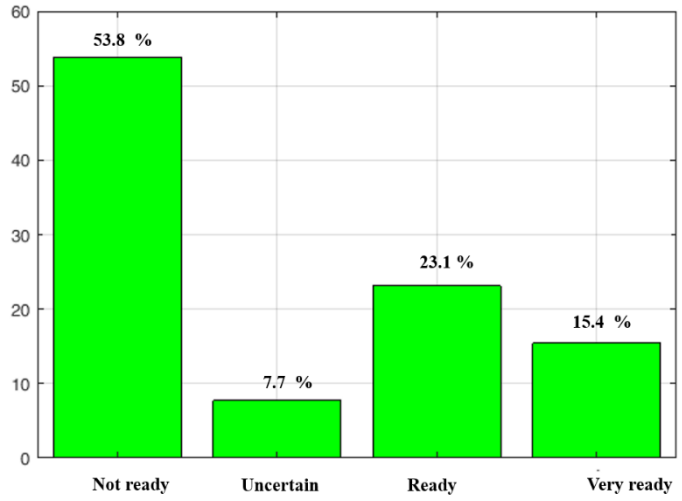


3(a)



3(b)

Qn. 7 How adaptable are you for 4IR technologies in teaching and research?



3(c)

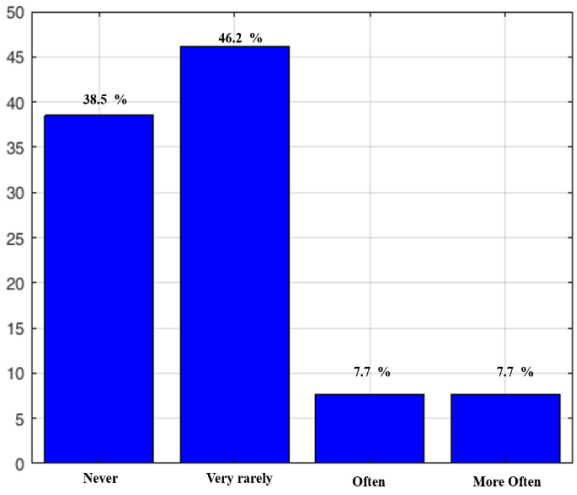
Figure 3: Questions on the Academicians' knowledge of 4IR technologies

3.2 Questions on the academicians' perception and application of 4IR technologies

Qn. 8, Qn. 9, Qn. 10 and Qn. 11 are related the academicians' perception and applications of 4IR technologies. Qn. 8, checks the degree of application of 4IR technologies during teaching. Qn. 9, highlights the application of 4IR during engineering research. Qn. 10, highlights the relevance of 4IR technology in engineering education and Qn. 11 gave an idea about the opportunities that academicians see in the use of 4IR technologies in engineering research and teaching.

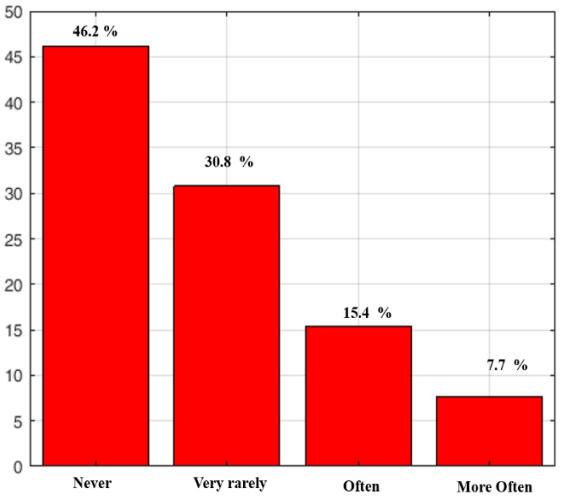
Results in Fig. 4(a) shows that, 84.7% of academicians are rarely and never use 4IR technologies during university teaching. Fig. 4 (b) shows that more 77 % of academicians are never and rarely use 4IR technologies during research. This indicates that there is still low application of 4IR technologies in engineering teaching and research in Ugandan universities. In Fig. 4(c), the academicians are aware that 4IR technologies are relevant in university engineering teaching and research. This is indicated high percentage of more than 84.6%. The academicians also seem to agree that level of importance attributed to the ability of use augmented 4IR technologies in engineering research and teaching is very important as depicted in Fig. 4(d).

Qn. 8 How often do you apply 4IR technologies in teaching or lecturing?



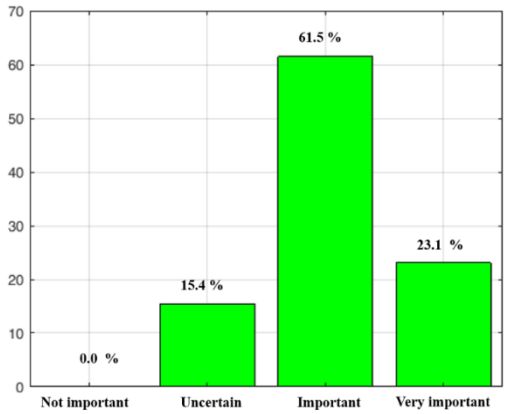
4(a)

Qn. 9 How often do you apply 4IR techniques in your research?



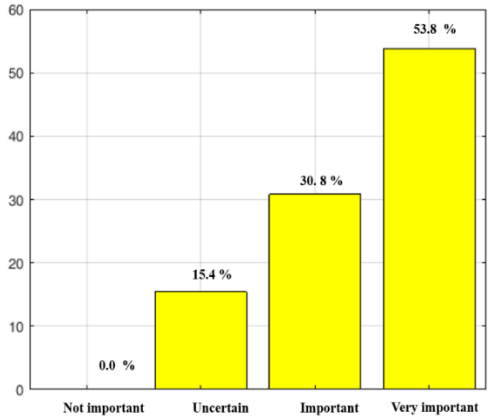
4(b)

Qn. 10 How relevant is 4IR technologies in your research and teaching?



4(c)

Qn. 11 What do you think is the level of importance attributed to the ability of use augmented 4IR technologies in engineering research and teaching?



4(d)

Figure 4: Questions on the academicians' perception and application of 4IR technologies

5. Conclusions

The results highlighted that the academicians in the engineering section in the seven universities in Uganda do not have enough teaching and research tools for 4IR technologies, and they aware of 4IR technologies and embraced its relevance. The findings also disclose that the majority of the academicians are not ready for 4IR technologies and those technologies are not widely spread in their current curriculum, and there is limited application of 4IR technologies during university engineering research and teaching.

In Future, it is also expected to investigate how 4IR technologies are perceived in their business sectors particularly in the small medium enterprises (SME) and craft firms.

References

[1]. Schwab, K. "The Fourth Industrial Revolution." [Cited 23 April 2019]; available from: https://www.britannica.com/topic/The-Fourth-Industrial-Revolution-2119734 2018.

[2]. Darwish, H. , "Expanding industrial thinking by formalizing the industrial engineering identity for the knowledge era." *PhD Thesis*, Potchefstroom: North-West University 2018.

[3]. Benešová, A. and Tupa, J., "Requirements for education and qualification of people in Industry 4.0." *Procedia Manuf.*, vol.11, pp. 2195-2202, 2017.

[4]. B. Motyl, G. Baronio, S. Uberti, D. Speranza, and S. Filippi, "How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey," *Procedia Manuf.*, vol. 11, pp. 1501–1509, Jan 2017.

[5]. T. Wallner, and W. Gerold. "Academic Education 4.0," *Int. Conf. on Education and New Developments*, WIARS Publishing, Lisbona, pp. 155-159, 2016.

[6]. B. E. Penprase, "The Fourth Industrial Revolution and Higher Education," SpringerLink, pp. 207–229, 2018.

[7]. J. Basl, "Pilot study of readiness of czech companies to implement the principles of industry 4.0," *Management and Production Engineering Review*, vol. 8, 06 2017.

[8]. W. Maisiri, H. Darwish, and L. van Dyk, "An Investigation of Industry 4.0 Skills Requirements," *S. Afr. J. Ind. Eng.*, vol. 30, no. 3, pp. 90–105, Nov 2019.

[9]. M. F. Kamaruzaman, R. Hamid, A. A. Mutalib, and M. S. Rasul, "Comparison of Engineering Skills with IR 4.0 Skills," *International Journal of Online and Biomedical Engineering (iJOE)*, vol. 15, no. 10, pp. 15–28, Jun 2019.

[10]. Xing, B., Marwala, T., "Implications of the Fourth Industrial Age for Higher Education". *The Thinker*, Issue73, Third Quarter, 2017.

[11]. R. Metraglia, V. Villa, G. Baronio, R. Adamini, R. "High School Graphics Experience Influencing the Self-Efficacy of First-Year Engineering Students in an Introductory Engineering Graphics Course." *Engineering Design Graphics Journal*, 79(3), 16-30, 2015.