A Bachelor Degree Program in IoT Engineering: Accreditation Constraints and Market Demand

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Abstract—In the era of the fourth industrial revolution, technology is advancing at a pace much faster than what individuals, societies and nations can cope with. Internet of Things (IoT) is one such technology that is sweeping the economic, business and service landscapes with its disruption mechanisms that influence areas such as smart homes, hospitals, cities, as well as transportation and energy utilization with many exciting and novel applications. Additionally, the job market is evolving at a rate that makes it difficult for universities to sustain a stable programme structure, especially in engineering and information and communication technology disciplines as well as specializations and domains associated with technology. While several universities worldwide have established IoT degree programs at bachelor and master levels, institutions in developing countries are still contemplating the idea of pioneering such venture due to a number of reasons related to technology vacillation as well as market and social acceptance. Princess Sumaya University for Technology has therefore designed a bachelor degree programme on IoT Engineering in order to bridge the gap in the Jordanian ICT market and to meet demands for specialized engineers in this rapidly evolving area. The university adapted an optimization design process of the program including a cycle of consultation with stakeholders, followed by a formal procedure of rectification and accreditation. The proposed program was successfully a launched at the beginning of the academic year 2021/2022 with an intake cohort of 50 students.

Keywords—IoT engineering, bachelor degree program, future jobs

1 Introduction

Industries worldwide are adopting Internet of Things (IoT) technologies as they digitally transform the traditional manufacturing and commerce sectors by embracing complex machines and intelligent systems in order to enhance efficiency, increase productivity and improve quality of products and services. In fact, IoT is fueling the fourth industrial revolution and driving the growth of the global market invariably and continuously. Market forecast reports such as Mordor Intelligence, Allied Market Research, and Zion Market Research, predict large market share of IoT that might reach, according to Fortune Business Inside, $1,854.76 billion by 2028, at a compound annual growth rate (CAGR) of 25.4% in the forecast period 2021-2028 [1]. Global ICT giants such as Hewlett Packard Enterprise, Intel Corporation, Hitachi, Amazon Web Services, Fujitsu, Cisco Systems, Huawei Technologies and Microsoft are the major players in IoT industries [2]. IoT is actually finding applications in many vital areas such as healthcare, agriculture, manufacturing, construction, energy management, self-driven cars, maritime, and military. In addition, IoT involves a wide range of technologies, which presents immense opportunities for students to opt for jobs such as cloud computing, software development, infrastructure architect, systems administrator, data scientists, cyber security expert, and test and sensor engineering. Initiative such as the Trillion Sensors (TSensors); initiated at Stanford University in 2013, amplifies further the demand on IoT as it pushes towards a concept of globally-connected network of where one trillion sensors are utilized and every citizen would use approximately 140 sensors every year, thereby attaining a world of abundance for people to receive education, food, medicine and healthcare in a disaster-resilient and clean-energy environment, thus creating a universe which requires a drastic demand on IoT specialists and experts and hence the creation of an entirely new high-skilled market [3].

IoT in education has been the subject of many surveys in recent years in order to highlight the utilization of IoT applications in various learning and training settings [4-7]. However, IoT education itself has been addressed only as a course within existing bachelor or master degree program, and seldom as an independent university specialization. In fact, very few universities in the world, other than China, offer a stand-alone undergraduate degree program in IoT due to issues such as deciding on pedagogy and curriculum settings, educational planning, and lack of unified definition and specific goals for training future IoT professionals. In this paper, the design of a bachelor degree program on IoT Engineering is described, in addition to the dispute around its creation and the challenges faced in its set up during a stakeholder consultation process. The design of the curriculum followed a closed-loop technical knowledge map (TKM-map) which connects theoretical courses to practical laboratories and technical training across the different layers of the curriculum [8], while respecting ABET accreditation criteria and the Jordan national qualifications framework hierarchy [9].

2 IoT definition, aliases and hype

IoT carries different names, has no universally accepted definition or standardized architecture, embraces a multitude of technologies, and finds applications in almost every occupation. IoT is, in fact, a melting pot of sister emerging technologies such as big data, cloud computing, blockchain, cyber security, communication networks, sensors and nano-devices and artificial intelligence, to name a few. However, the debate on a unified definition for IoT continues after over two decades of its inception. The US National Institute of Standards and Technology (NIS) report, for example, considers IoT as a subset of network of things (NoT), where a wide range and diverse set of devices with incorporated sensors are connected to the internet to generate, collect and exchange data in machine-to-machine (M2M) configuration, with or without human interference [10]. Several attempts have been made to define IoT in the line of being "an open and comprehensive network of intelligent objects that has the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment", with an emphasis that the data created is by things rather than people [11].

There has also been a debate on IoT terminology with several aliases that include internet of everything (IoE), internet of people, "networks of things (NoT) [12], web of things, internet of nano things (IoNT), internet of objects, embedded intelligence, connected devices and technology omnipotent, omniscient and omnipresent [13]. Nonetheless, the term IoT has prevailed over other names, and the technology has flourished over the last two decades as reflected in the "Gartner Hype Cycle" shown in Figure (1). The cycle actually describes the evolution of certain technologies overtime, thereby providing a sound source of knowledge to manage its implementation within the context of the business objectives. Technologies follow five stages that range from conception to the actual development of products and services, beginning with the technology trigger, peak of inflated expectations, then the trough of disillusionment, slope of enlightenment until arriving at the plateau of productivity as products become available in the market. The cycle also anticipates the estimated years required a specific technology to achieve the plateau of productivity.

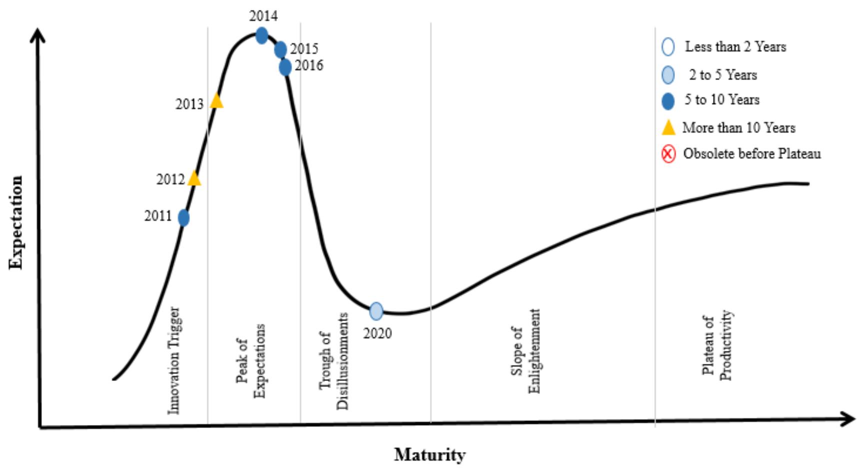

Fig. 1. IoT evolution on Gartner hype cycle of IoT since 2011

IoT has actually entered the hype cycle in 2011, peaked in 2014, reached the bottom of the trough of disillusionment in 2020, and currently climbs out towards the slope of enlightenment. Furthermore, IoT has been allocated a special hype cycle of its own since 2016 which contains assessment of 29 IoT innovations that progressed along the curve with various degrees of adoption and maturity. The IoT cycle for 2021 anticipates eight transformational and six high-impact IoT innovations to enter mainstream adoption within 2-5 years, as shown in Figure (2). Some of these IoT emerging innovations include master data management (MDM) technology-enabled business discipline in which business and IT work together to maintain various properties the shared master data assets of the enterprise, IoT enabled services and products, things as customers, IoT and blockchain, IoT-enabled applications, all of which are still at the technology trigger phase. At the peak of expectation phase lies the digital thread, which describes the framework that connects data flows and produces a holistic view of an asset's data across its product lifecycle. IoT services, IoT healthcare, IoT security, IoT edge architecture, and IoT platform are technologies going through the trough of disillusionment phase, while managed IoT connectivity service and IoT integration are both approaching the plateau of productivity, as of 2021, as shown in Figure (2).

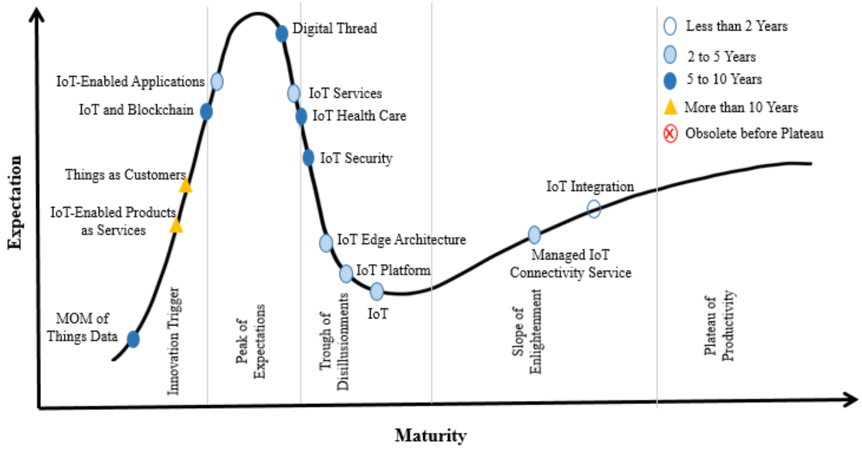

Fig. 2. Gartner hype cycle of various IoT technologies, as of 2021

Although the cycle is not scientific in nature as compared to the rigorous technology readiness level (TRL), it gives a sensual and conceptual presentation of the degree of technology adaptation over a certain period. This matter calls for further studies to categorize and assess IoT technologies by mapping them onto TRL [14] as well as the technology readiness index [15]. The TRLs is actually a NASA-devised method based on a scale 1-9 to estimate the maturity of a certain technology during the acquisition phase in order to examine its concepts, requirements, and to demonstrate its capabilities.

3 Global survey of IoT programs and courses

Universities worldwide have started to offer master and bachelor degree programs in IoT as well as certification and online courses as shown in Table (1). Prestigious universities such Stanford University, MIT, University of California and Oxford University opted for the choice of integrating IoT courses in existing programs or as MOOCs. Stanford University; for example, offers an IoT certification program in lieu of a degree comprising 15 different short courses to tailor for the learner interests and career goals. Several platforms such as Coursera, edx, and FutureLearn offer online courses in IoT as MOOCs including: Introduction to IoT and Embedded Systems, IoT and Augmented Reality Emerging Technologies, A Developer's Guide to IoT, IoT: Setting Up Your DragonBoard™ Development Platform, IoT: Sensing and Actuation from Devices, Cybersecurity and IoT, Architecting Smart IoT Devices, Enabling Technologies for Data Science and Analytics: The Internet of Things, IoT Networks and Protocols, IoT Sensors and Devices, and IoT Programming and Big Data. Most of these courses are free with optional upgrade for fee, short in period of few weeks, 2–3 hours per week, self-paced where learners progress at own speed and taken by individuals who seek knowledge in the subject and wish to receive a training certificate. An Introduction to Programming IOT, offered by University of California/Irvine on Coursera, attracts 404000 students, while the MOOC on “Machine Learning”, designed by Stanford University is the most all time popular course with over 4.6 million students completing it successfully. Few MOOCs are accredited or taught in universities worldwide, including the most popular ones.

Voices from industry worldwide initiated a call for universities to offer IoT courses and programs as demand for graduate skills have grown exponentially in recent years with the emergence of new technology and applications, and as governments started placing the subject as one of their strategic objectives. Such voices argued that in order to provide fully relevant experience to incoming students, modern universities must begin designing degrees on cyber-physical systems and IoT implementations. Table (1) also shows universities worldwide that offer courses, bachelor and master degree programs on IoT. In fact, Florida International University was the first institution to start offering a complete bachelor degree program in IoT engineering in the USA, while only two universities in the UK and one in Ireland that offer similar programs in the whole of Europe. Universities in Australia, Singapore, Malaysia, India and Pakistan have also established IoT programs for undergraduate students in either the computing or engineering disciplines with emphasis on specific technologies. Other universities such as Queen Mary, Royal Holloway and West of Scotland in the UK, Salamanca, Alcalá and CIFF Business School in Spain, Bourgogne Franche-Comté in France and Malmo in Sweden have focused on providing in-depth knowledge on IoT technologies by offering master degree programs. The programs mainly combine the domains of electronic engineering and computer science, and covering areas such as intelligent sensing, sensors, data mining and visualization, wearables and ubiquitous sensors, data science, analytics techniques and big data acquisition, RFID, cloud technologies, industry 4.0 emerging technologies, programming and telemetry protocols, cyber-security and technical and methodological aspects of distributed and networked systems.

Table 1. MSc and BSC Programs and Individual Courses in IoT in Universities Worldwide

Level	Title	University	Country
Course/MOOC	IoT Certification Program	Stanford University	USA
	IoT: Business Implications and Opportunities	MIT	USA
	IoT: Road Map to a Connected World		
	IoT Specialization-MOOC-Coursera	California/San Diego	USA
		California/Irvine	USA
	Data Science for the IoT	Oxford	UK
	The IoT-Future Learn	King's College-London	UK
	Internet of Things/MSc (Advanced Computer Science Program)	Liverpool Hope University	UK
	Internet of Things and Applications/ MSc (Cyber Security and Big Data Program)	Loughborough	UK
	Mobile Computing and the Internet of Things/MSc (Advanced Computing Technologies Program)	Birkbeck	UK
	IoT and Augmented Reality Emerging Technologies-Coursera	Yonsei	South Korea
	IoT for Active Aging-Future Learn	Taipei Medical	Taiwan
Bachelor	IoT	Sydney	Australia
	Engineering/Electronic Systems and IoT	James Cook	Singapore
	IoT	Xi'an Jiaotong-Liverpool	China-UK
	IoT Engineering	Beijing Dublin International	China-Ireland
	IT in IoT	Kuala Lumpur	Malaysia
	IoT	Asia Pacific	Malaysia
	Computer Science and Engineering- IoT	Petroleum and Energy Studies (UPES)	India
	IoT and Edge Computing	Dehradun Institute of Technology (DIT)	India
	IoT	Management and Technology	Pakistan
	IoT	National University of Computer and Emerging Sciences	Pakistan
	IoT	Huddersfield	UK
	IoT	De Montfort	UK
	IoT/Applied Computing	Waterford	Ireland
	IoT	Florida International	USA
Master	IoT	Bourgogne Franche-Comté	France
	IoT	Queen Mary	UK
	IoT	Royal Holloway	UK
	IoT	West of Scotland	UK
	IoT	Salamanca	Spain
	IoT	Alcalá	Spain
	IoT	CIFF Business School	Spain
	Computer Science (IoT)	Malmo	Sweden

China, on the other hand, has launched independent IoT Engineering programs at the undergraduate levels in over 700 universities since 2011. Most of these universities have followed the full coverage mode in the design of the program study plan by incorporating courses across the sensing, network, supporting and application layers of the IoT framework. Few universities adopted the biased coverage mode with the choice of curricula based on faculty specialization and professional training rather than the actual need of industry and marketplace. The majority of these universities have placed the program in computer science departments with courses focused on IoT software, systems and applications. Other universities set up the program in the electrical engineering or communications engineering departments with curricula focused on IoT sensing and control technologies, specifically on sensors, RFID, microcomputers, and embedded systems and on networking, wireless communications, information sensing and processing.

4 IoT study plan

One of the most important goals of the Princess Sumaya University for Technology (PSUT) is to continue prepare the future generation of Jordanian engineers to be innovative leaders and creative entrepreneurs. The university has actually embarked in launching a series of graduate and undergraduate programs to keep abreast with a multitude of emerging technologies, such as artificial intelligence, big data, cyber-security, and information systems security and digital criminology. As IoT technology has become a daily reality; and theoretically encompasses almost all areas of life, including medicine, economics, luxury, sports, and others, experts expect the size of the its market to exceed the combined market of cell phones, computers and tablets. Most of the investment in this sector may be spent on operating systems and software for these devices, the home automation sector is its largest market, while systems infrastructure is expected to be the most important government projects in this regard. Based on this, the reasons for opening the program focus on:

1. Providing the state with specialized experts in IoT engineers to deal with future needs that arise because of the development of the technologies of the fourth industrial revolution.
2. Spreading the spirit of entrepreneurship in the coming generations and urging them to go towards developing their own technological products provided by emerging technologies, instead of seeking and waiting for employment.
3. Motivating and encouraging students to pursue scientific research in IoT and the emerging technologies associated with it in order to keep pace with global scientific progress.

The Communications Engineering Department has thus initiated a process to establish a new bachelor degree program in IoT Engineering during the summer of the academic year 2019/2020. It was important then to align the new program to the ABET accreditation requirements in anticipation of receiving future endorsement following the footsteps of its sister programs. Accordingly, certain criteria were observed when deciding on the program learning objectives and students' outcomes. A debate on the learning outcomes of the program has consequently been concluded with emphasis on the graduates to:

- pursue successful careers and actively contribute to team spirit as entrepreneurs and leaders.
- apply the acquired knowledge in community service and appreciate ethical and professional responsibilities.
- demonstrate motivation in learn continuously and adapt to changes and developments in the world of technology.

Hence, upon completion of the programme, the graduate should be able to:

1. Identify, design, analyze, program, and test the components that make up parts of IoT architectures, and implement practical real-world models and systems to integrate with the latest technologies.
2. Evaluate and analyze appropriate protocols for communication between IoT devices and systems.
3. Understand where the concept of the IoT fits in with the broader ICT industry and potential future directions.
4. Estimate the role of bigdata; cloud computing, artificial intelligence and data analysis in a model.
5. Define theories, research and applications in the disciplines related to IoT.

The simplest approach to establish such an undergraduate IoT Engineering program was to combine existing core courses on devices, programming, communications, and data processing from various departments in one pool and create a loosely connected study plan. However, the connection between the courses in such a case is usually random, weak and short of providing students with profound IoT knowledge, skills and competencies regardless of the coverage mode; whether full or biased. Instead, a convergent curriculum system based a technical knowledge map comprising a multi-layer framework with supporting technologies that cover all major IoT areas has been adopted as proposed by Bing Du et al to serve as a reference [8]. The core courses follow a bottom-up approach and stem from the fundamental theories to the advanced applications with the aim to cover most aspects of IoT industries. The framework consists of four layers encompassing IoT technologies, mainly the sensing, transmission, processing and application layers, together with algorithms and cyber security as the two overarching technologies, as shown in Figure (3). Although the courses and study plan layout have been chosen prior to the date of proposition of Bing Du et al work [8], it actually followed the same logic of the map independently.

The allotment of courses within sensing layer were set according a sequential flow starting from the circuit theory courses to embedded systems covering both data and communications fields. These courses include electric circuits 1 and 2 and electric circuits lab, logic design and its lab, electronics 1 and 2 and electronics lab, automatic control, in addition to embedded systems and lab and introduction to IoT. Signal and systems, digital signal processing (DSP) were placed in the communications field within the sensing layer too. The courses in the transmission layer followed a design concept that stems from point-to-point communication to network information theory and technologies. The courses in this layer were electromagnetics, communication principles and lab, cellular communication and lab, communication networks and lab, antenna and wave propagation, IoT cloud computing, robot IoT, wireless IoT and lab, and IoT protocols. Similarly, the courses in the processing layer followed the design concept of technology requirements for storage and computing, and included courses such as discrete math, linear algebra, engineering math 1 and 2, probability and statistics, AI and machine learning, object oriented programming and lab, basic database and lab blockchain and IoT. Finally, in the application layer, the focus was mainly on implementation of IoT systems in real life situation, practical laboratories and fieldwork. These courses included IoT application and sensors and lab, automotive vehicles, in addition to a design project 1, design project 2, field training, and the complete design of an IoT platform. A number of elective courses were introduced to the study plan that included courses covering all layers and overarching technologies such as the courses on blockchain and IoT, cloud computing in IoT, internet of robotics, automotive vehicles, as well as other special topics students may choose to take three courses from this basket of electives. Some of the courses may actually extend from the sensing or processing layers to the transmission layer as shown in Figure (3).

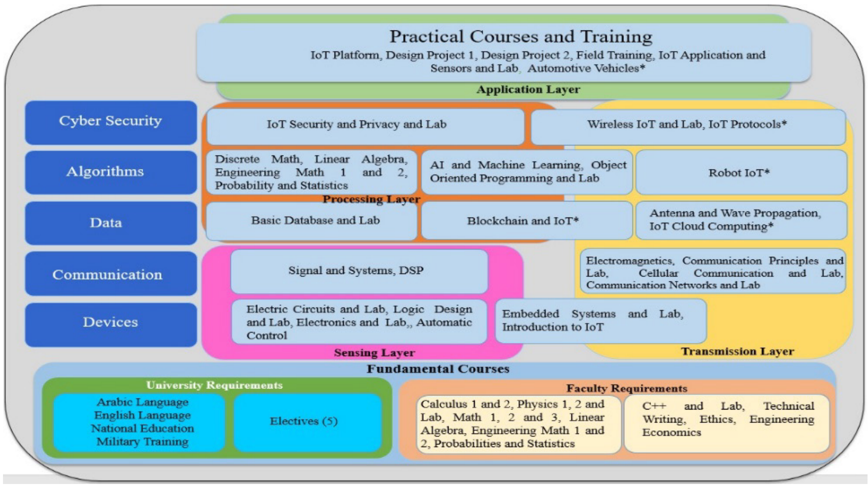

Fig. 3. The technical knowledge map of IoT talent

A number of constrains governed the design of the study plan, namely the rules set out by the higher educational authorities that divide every bachelor degree program into university, faculty and departmental requirements. The total credit hours of university requirements is 27 while the faculty requirements amount to 30 credit hours. This leaves 103 credit hours for the particular engineering program, nine of which are electives chosen from the basket of electives.

The rules of the Accreditation and Quality Assurance Commission of Higher Education Institutions (AQACHEI) place other constraints on every program that must adhere. These rules pertain to the inclusion of specific knowledge fields that must be covered, including 30 credit hours of mathematics and science, 12 credit hours of basic engineering sciences, 9 credit hours of fundamentals electrical engineering, 6 credit hours of computer and communications, and 6 credit hours of control and power. The compulsory knowledge fields amount to 39 credit hours that include basics of IoT, computing of IoT, artificial intelligence, IoT security, communication systems, signal analysis, and wave propagation. As such, the overall distribution of the study plan is shown in Figure (4), where the percentages of courses of this multidisciplinary IoT engineering bachelor degree program are allocated according to constraints, requirements, and disciplines. A total of 30 credit hours (18.75%) out of 160 are actually pure courses devoted to IoT, while 16.88% were allocated to university requirements, 18.75 to faculty requirements, and 21.25% to general electrical engineering courses. The remaining 39 credit hour were borrowed from a pool of courses offered by the communication engineering, computer engineering, and network engineering and computer science programs, almost equally with 6.25% of the total credit hour each, as shown in Figure (4).

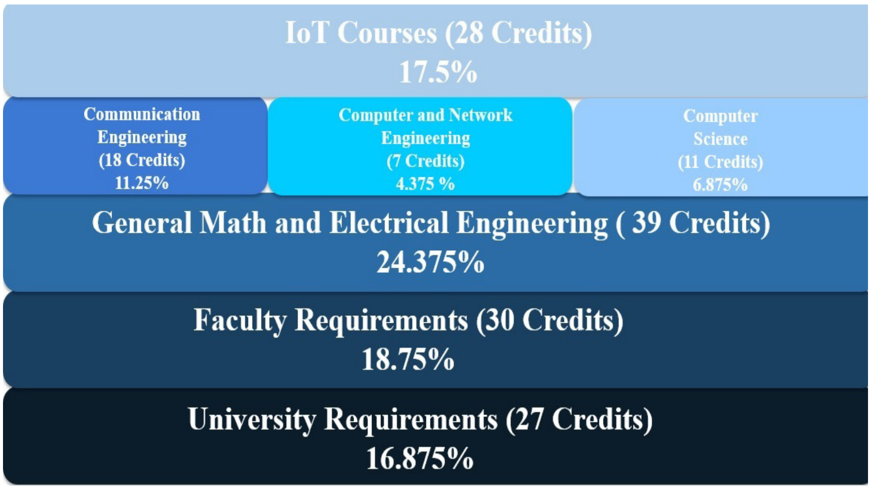

Fig. 4. Distribution of courses over study plan fields of specialization

The proposed IoT BSc program could easily fit the criteria of incorporation in the Jordan national qualifications framework by positioning it at level 7 in a 10-level hierarchy designed for both academic and vocational pathways [9]. The descriptors of the framework were formulated in terms of learning outcomes in order to reinforce the orientation of education, training and qualification systems in terms of knowledge, skills and competencies. The descriptor of level 7 incorporated knowledge that provides learners with good understanding of theories, concepts, principles, and generalizations pertaining to IoT, as well as methods of scientific research and ways of employing them in the field. In addition, the descriptor describes the acquire skills to demonstrate mastery and propose innovative solutions required to solve problems in IoT engineering taking into account the related theoretical knowledge and practical experience. Finally, level 7 descriptor deals with competencies to manage technical activities, projects or groups; fully cooperate with others, taking responsibility for decision-making in IoT related matters. The level descriptor actually forms the foundation for employers and quality evaluators to identify the expected knowledge and skills of the graduates of the program, and enhance its integration among various educational sectors in Jordan and facilitate its recognition in other countries.

5 Stakeholders consultation and accreditation process

The proposed new study plan was first presented to the industrial advisory committee, which consists of five prominent experts involved in the private and public ICT sector in the country. The feedback received was documented and then followed by several online meetings for further discussions, and slight modification were subsequently incorporated in the plan. Subsequently, a list of stakeholders was prepared including university partners, potential players in the field, namely the Jordan Engineering Association, Information and Communication Technology Association (Intaj), Telecommunication Regulation Commission, Civil Service Bureau, Amman Municipality, Jordan Design and Development Bureau, and major telecommunication service providers and ICT enterprises. A series of interviews and meetings have been conducted with these stakeholders to investigate the stand of the local industry, ICT service market and government position on the need to produce IoT engineering specialists and professionals, and thus creating a specialized IoT Engineering program at the undergraduate level.

Furthermore, a generic 12-statement questionnaire was designed to probe the views of society and institutions on the idea and concept of the IoT field in general and proposed program in particular. The questionnaire was distributed to all stakeholder institutions, parents, alumni and even colleagues in other universities specials in ICT disciplines. The statements posed were:

1. There is a global trend in the industry towards IoT.
2. Introducing an IoT engineering program in Jordan is important.
3. There is currently a demand in the labor market for IoT experts.
4. There will be a demand in the labor market for IoT expertise in the future.
5. There is a lack of competent IoT expertise locally.
6. There is a lack of competent regional IoT expertise.
7. IoT engineering will enter the technological, industrial and service sectors in the immediate perspective.
8. There are good experiences in the field of IoT that attract regional and international companies to Jordan.
9. The proposed IoT Engineering study plan for the program is appropriate.
10. The subjects proposed in the plan provide graduates with the skills needed for the labor market.

11. The proposed IoT engineering program will demonstrate graduates' ability to work in various roles and as team members.
12. The program will polish the graduates' personalities and prepare them for leadership roles in the labor market.

A total of 129 responses were received as shown in Figure (5). The results show that respondents see that there is a strong global trend in the industry towards IoT (97%) and that IoT engineering will enter the technological, industrial and service sectors in the immediate perspective (94%). Meanwhile there is currently a fair demand in the labor market for IoT experts (75%), but should prepare for the future as there will be a greater anticipated demand (93%) due to a lack of competent IoT expertise locally (94%) and regionally (97%). Consequently, the respondents believed that it was important to introduce an IoT engineering program in Jordan (88%) because of the good experiences that attract regional and international companies to Jordan (72%). The respondent viewed the proposed IoT Engineering study plan positively (79%), which provide graduates with the skills needed for the labor market (81%), demonstrate their ability to work in various roles and as team members (79%), and may polish their personalities and prepare them for leadership roles in the labor market (85%).

Several feedback comments indicated that the proposed program is sound and appropriate with a proactive view on the future of the labor market. In addition, the IoT sector will flourish if the country encourages economic policies and international investments through tax laws and the availability of appropriate infrastructure. The program should; however, include courses related to IoT from the first year with focus on practical and applied technologies to empower students with a higher readiness suitable for the labor market. Others proposed adding programming languages such as Python and big data for IoT and its applications in the fields of automation, removing specialized and in-depth materials in the field of electronic engineering in favor of the new specialization, as well as adding materials for project management. Some respondents suggested an increase in IoT subjects by reducing university and faculty requirements, while fostering practical laboratories associated with current companies and softwares, particularly in the IoT and Blockchain course. The optional IoT subjects were also seen as the core of the program and their technological connections perceived more much important than some other subjects did in the plan. In addition, topics related to IoT such as healthcare, lightweight IoT encryption algorithms, smart home and smart city may have been overlooked in the study plans, which should emphasize more practical and applications supported by the relevant industries. Some recommend communicating with the Greater Amman Municipality, as it is working to transform the capital into a smart city, which calls for directing students to implement related projects that benefit the city and students at the same time.

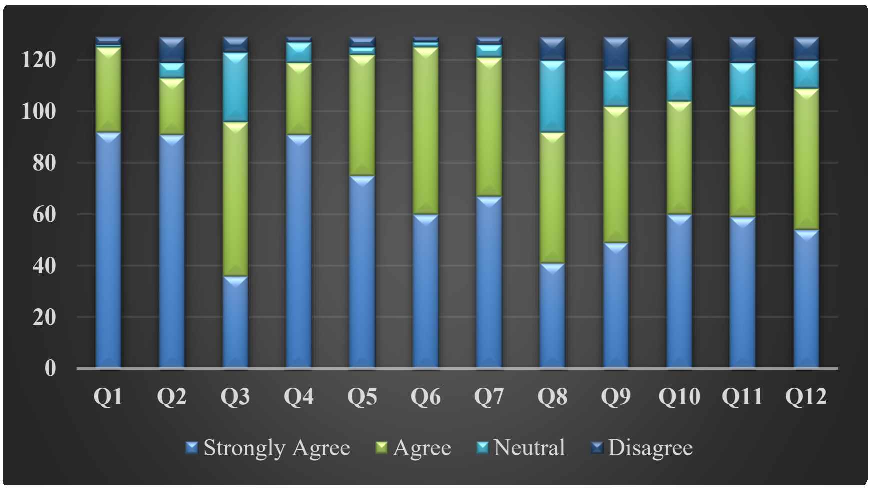

Fig. 5. Responses on IoT engineering program viability and feasibility

On the other hand, few respondents think that IoT does not require a four-year BSc specialization. In the contrary, they see it as a sub-discipline of information sciences or related discipline, while others prefer that such a program be offered as a master degree and not at the bachelor level as it does not amount to a specialty in itself. Hence, several respondents suggested that the program might be combined with other disciplines such as robot engineering or as part of artificial intelligence and big data engineering. Such conservative comments about setting up an IoT major at the undergraduate scale are strikingly similar to those surfaced during a dispute on the topic in China. In fact, this view was surprisingly echoed at the top level of the Chinese IoT Industry Association since IoT is viewed as interdisciplinary field that involves a wide range of knowledge, hence placing great challenges for a university to design an exclusive program, which covers the full aspects of IoT technologies and applications.

6 Discussion

Despite the fact that several experts in the ICT field recognize the importance and promise of IoT technology, as well as how it fits into the overall digital transformation, they were hesitant to standardize one paradigm or establishing a specific stand-alone engineering program in IoT at the bachelor degree level. The next major challenge encountered in this endeavor was not only overcoming resistance to change, but rather to embrace all conflicting and opposing viewpoints on the focus of the program, let alone its philosophy. Another key challenge was determining how to develop the study plan of the IoT Engineering program while keeping in mind the mission and vision of the university as well as all other imperatives and requirements in a finite curricula area. Fortunately, recent studies have provided clear support to the idea as experts predict that approximately 22 million jobs worldwide will be created and the global revenues will reach about 12.3 trillion US dollars by 2035, because of the anticipated changes that 5G will bring about in various forms of lifestyles. Jordan should thus seize such an opportunity, or even imperil, in order to prevail over the mounting challenges presented by an enormous amount of demand for employment in the labor market, where almost every scientific and engineering discipline has already been saturated with skilled workers. In fact, the country is witnessing unprecedented figures in unemployment amongst its highly educated youth, constituting over 30% of its population. The modest, low-growth and pandemic-stricken industry must consequently find ways to rejuvenate the labor market diversity by introducing new programs to deliver the highly-skilled needed talent, that is aligned with newly create jobs and professions relevant to the prevailing workplace.

To that end, the IoT Engineering curricula was designed in order to equip students in Jordan with the necessary professional skills needed to tackle the alternative techniques in a variety fields such as virtual reality applications, remote surgery, as well as the connections of self-driving vehicles, massive number of sensors for agricultural and environmental systems. Hence, tailored courses to address these aspects were integrated into the study plan such as wireless IoT, autonomous vehicles, communications networks, smart-grids, communications protocols, virtual reality, multimedia communications, and sensors networks. Furthermore, the study plan was designed to cover a wide range of knowledge domains that cover the majority of aspects of IoT theory and applications. These knowledge domains provide students with the skills needed for future multidisciplinary IoT based jobs. Likewise, the IoT labs present students with a unique opportunity to gain hands-on experience with some of the IoT sensing and control technologies. Moreover, the program curriculum emphasizes contemporary and future trends in the ICT field with a primary focus on IoT matrix enablers encompassing smart city communications, and the 5G cellular communications system, which are vital for IoT contemporary systems.

As a result, some current IoT programs offered by other international universities were investigated, while taking into account stakeholders' feedback and their expectations, which were the primary drivers in developing the rough draft of the study plan. The Chinese experiment of launching similar programs since 2011 in over 700 universities has been particularly motivating because it represents a rich and culminating experience with many lessons to share. The recent review study of Bing Du et al on surveying the history, status, curriculum, and problems of IoT undergraduate degree programs in China was invaluable tool to benchmark and use as a reference [8]. Although the proposed IoT program was designed and launched prior to this publication, the structure of the study plan bears a striking resemblance to the closed-loop technical knowledge map proposed by Bing Du et al, which can be utilized as a guide to connect theories with practical training for IoT Engineering undergraduate programs. Fortunately, the proposed study plan has followed the logic of such TKM-Map with a similar four-layer framework structure that covers the most important elements of IoT industries, services, and applications, particularly those relevant to the Jordanian and regional job markets.

The study plan was initially scrutinized by higher quality assurance committees at the faculty and university levels and all feedback and suggestions were discussed, taken into account and appropriate modification were made. The university has then submitted an application to the higher education council, requesting the creation of the IoT Engineering program by the end of February 2021. Initial approval was subsequently granted following a debate on the maturity of standards, technologies, business models, and supporting policies related to IoT. Final endorsement of the program was issued subsequent to further discussion with the Accreditation and Quality Assurance Commission of Higher Education Institutions (AQACHEI) on the challenges imposed by the shortages of qualified professors dedicated to IoT, professional teaching materials, and specialized laboratories and practical platforms, which may result in a gap in training highly skilled IoT talent. The debate has taken place to ensure that the study plan complies with the current QA rules; in particular, the urgent condition to recruit two professors specialized in IoT disciplines. Henceforth, the university has officially established the program, receiving the first cohort of 50 students at the beginning of the academic year 2021/2022. It is strongly believed that commitment to continuous improvements is the right way to reach the optimum study plan. To accomplish this goal, a plan is being developed to establish two committees, the first of which is an engineering industrial advisory committee (EIAC) and the second of which is an engineering student advisory committee (ESAB), both of which will serve as an additional resource for receiving feedback through the continuous improvement process.

Setting up an integrated IoT platform that supports specific research topics to assist students in practical training programs remains one of the most intriguing recommendations gleaned from Chinese universities experience [8]. A university–enterprise partnership, on the other hand, may be the most effective way to fulfill such a bequest, especially if it can be accomplished through an international cooperation operation in the country in the field of IoT or one of its derivatives. Efforts are currently being made to identify a suitable enterprise in order to initiate collaboration in the form of offering intern opportunities as practice cases to students to participate in actual practical projects that take them through the workflow, familiarize themselves, and adapt to the enterprise teamwork of [8]. In addition, the university will identify the most suitable MOOCs to integrate onto the study plan and hence initiate contacts with popular open platforms to seek partnership and collaboration in this matter. Furthermore, the university will continuously monitor the annual IoT Gartner hype cycle report in order to observe technology vacillation and trends that could be taken into consideration during the revision and update period.

7 Conclusions

An optimization design process of a state-of-the-art bachelor degree program on IoT Engineering was described based on the convergent curriculum approach spearheaded by a 4-layers technical knowledge map with the support of algorithms and cyber security as the two overarching technologies that spread over IoT areas. Princess Sumaya University for Technology strongly believed on the significance of IoT education and research, and subsequently opened this undergraduate program despite the ongoing controversy about whether it should be regarded as a stand-alone bachelor major or offer at the more convenient master level. The mounting challenges faced in the program's set up were also addressed during a stakeholder consultation process, mainly considerations pertaining to the immaturity of the field, vague business model and lack of national IoT strategy and policy. In addition, fears of inadequate infrastructure and academic requirements as well as students' turnout were the central pillars of the dispute around the viability of the program, and measures to dissipate and overcome such fears have been taken into consideration.

The program has shown early signs of success measured by the turnout of students at its inception, indicating a reasonable demand on the topic in the immediate future. Higher students demand on the program is anticipated since it is the first of its kind in the country and the region, with the attention of the university to seek ABET accreditation once all requirements are ensured. However, adopting an appropriate IoT platform to serve as a practical tool at the application layer remains one of the most ambitious and immediate steps to undertake. Further development and modifications on the study plan are inevitable as IoT technologies evolve and as self-experience matured. Consequently, the proposed program will be subject to scrutiny and revision in an annual basis.

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