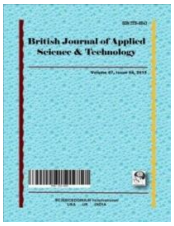

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The Engineering of an Undergraduate Nuclear Education Program in Jordan

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Recognizing the vital importance of nuclear knowledge and that human capacity building is the first step in the effective planning and implementation of a successful nuclear power program, in 2006/2007 Jordan made the decision to establish a nuclear engineering education program. The establishment of such a program was the first step in Jordan's efforts to develop its nuclear infrastructure and to introduce nuclear power as part of its energy mix.
The Nuclear Engineering department to Jordan University of Science and Technology (JUST), is the first and only such department/program in Jordan. To provide top quality nuclear education that will lead to realistic teaching instruction this department was engineered and designed based on four factors; curriculum, faculty, facilities and students. This paper presents the establishment of nuclear engineering education in Jordan and the department role in building Jordan's human capacity to ensure the proper implementation of its nuclear power program; it further evaluates the department challenges and current status.

Keywords: Nuclear engineering; education; Jordan; human resources; University; JUST.

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1. INTRODUCTION

In 2007 the world witnessed an unprecedented number of countries expressing their interest or declaring their intention to peruse a nuclear power program for the first time. The vast majority of the 65 countries that approached the International Atomic Energy Agency (IAEA) for assistance in their nuclear programs are developing countries [1] fourteen are located in the Middle East, Jordan being one of them. The greatest challenge that most developing countries will face in their effort to introduce nuclear power will be the lack of qualified nuclear engineers and experts.

In 2007, Jordan announced that it plans to build and operate four nuclear power plants by 2015 [2,3]. Recognizing the vital importance of nuclear knowledge and that human capacity building is the first step in the effective planning and implementation of a successful nuclear power program, the nuclear engineering department was established at Jordan University of Science and Technology (JUST). The establishment of such a program was the first step in Jordan's efforts to develop its nuclear infrastructure [14].

The nuclear engineering department at Jordan University of Science and Technology (JUST), is the first and only such department/program in Jordan. This university itself is a leading Jordanian institution of higher education with more than 20,000 undergraduate students and 1800 graduates, including nearly 5000 international students from 60 different countries. The college of engineering is the heart of the university with eight specialty departments (Fig. 1) and approximately 7,000 students; the college is staffed with 158 professors distributed over the departments as shown in Table 1 [4].

Assuming the lead role of Jordan's nuclear human capacity building, through educating, training and graduating competent engineers that will ensure the proper implementation of Jordan's nuclear power program [5], the department accepted its first class of students in the same year (2006/2007).

Aiming to provide top quality nuclear education that will lead to realistic teaching instruction the department was engineered and designed based on four pillars: Curriculum, faculty, facilities and students [6,7].

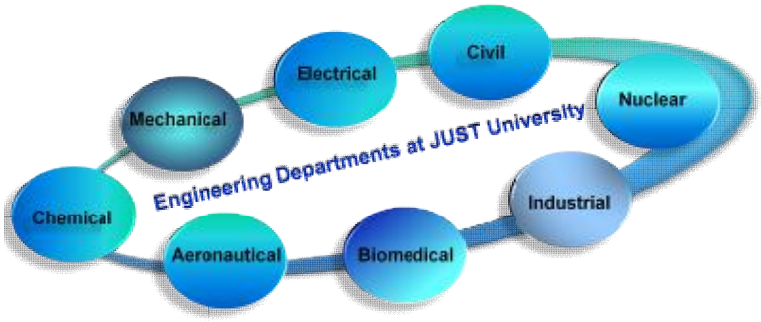

Fig. 1. Engineering departments at Jordan University of science and technology

Table 1. Number of professors and rank of the teaching faculty at the college of engineering departments

Department	Full professor	Associate professor	Assistant professor	Total
Aeronautical Engineering	0	3	2	5
Biomedical Engineering	2	2	5	9
Chemical Engineering	10	7	1	18
Civil Engineering	20	16	8	44
Electrical Engineering	15	8	9	32
Industrial Engineering	1	7	6	14
Mechanical Engineering	14	8	8	30
Nuclear Engineering	1	1	4	6
College Total	63	52	43	158

2. TEACHING FACULTY

The quality of teaching at any institution depends largely upon the quality of the faculty and academic staff. To ensure a top quality educational program, the department has to be staffed by faculty and academic staff whose graduate and undergraduate work is in nuclear engineering or graduates with practical experience in the nuclear field and who have gained an adequate amount of nuclear knowledge, to be transferred to students [14].

The enormous challenge that will face the university will be staffing the department with such high caliper people. The present university salary system where all professors regardless of their achievements or qualifications and whether they teach music or rocket science earn the same salary [14], is obsolete and would definitely undermine the department strategic plan and hinder its success.

Search to recruit qualified faculty members should be a top priority, as this method makes more economic sense than sending individuals to obtain higher degrees at the expense of the university and contract with them to comeback and teach at the university, which seems to be common practice in most third world countries.

Straight through school PhD graduates do not necessarily make the best faculty for a startup department like the one in Jordan [14], especially in the absence of nuclear facilities, or basic nuclear and industrial infrastructure. With the lack of any nuclear experience and in the absence of supportive nuclear institutions candidates with BSc degrees in different engineering disciplines would remain poor in nuclear engineering since they missed most of the basic and fundamental education in that field.

The department started in the year 2006/2007 with one professor and has grown to have six professors in the year 2014/2015. The number of faculty have fluctuated randomly as a result of administrative decisions and not necessarily based on the department needs. As can be seen in Table 2, in the year 2011/2012 the department had 127 students and merely 3 teaching faculty members, resulting in the highest student to faculty ratio (42:1) over the last nine years [8,9].

In its 2011 report regarding the safety and operation of the department sub-critical reactor (JSA), an official mission of French experts concluded, “A good scientific expertise of University professors, trained abroad, associated with a lack of knowledge and practices in matter of safety and operation of nuclear facilities” [10].

Currently 50% of the faculty members are from the same family as the university president [8]. In fact, the majority of students sent by the university to study abroad were from that same family, which raises the question if the criterion was academic excellence or kinship and cronyism. The lack of integrity and equal opportunity will undermine any education system and will definitely affect not only nuclear engineering education but also the safety and security of the whole nuclear program in Jordan.

3. THE EDUCATIONAL CURRICULUM

3.1 Courses Offered by JUST

The curriculum was designed to focus on nuclear power engineering, in particular nuclear power from fission reactors. It is intended to educate students in the basics of nuclear technology, radiation measurement and power reactor engineering; furthermore, it gives the student a very strong background in basic sciences and engineering [14]. The nuclear engineering compulsory courses distribution base on their specialty area are tabulated in Table 3, the 64 credit hours (Cr. Hrs.) are distributed between 56 Cr. Hrs. for lectures and 8 Cr. Hrs. for laboratory. Thus over five years, the student receives 896 actual classroom hours and 384 actual hours in the laboratory, totaling 1024 hours of compulsory nuclear education.

The curriculum prepares students for careers in nuclear power, in regulatory positions with the government, or for employment with electric utility company to work on the design, building, testing, maintenance and operation of nuclear power plants. The curriculum also prepares the graduate for work in many areas where a broad technical background is more important than specialization in a specific field [14].

The curriculum features an important course that distinguishes it from most nuclear education programs worldwide [11] “Ethics and the introduction of nuclear energy”, is a course that introduces students to the ethical responsibilities that accompany working with nuclear energy. It also gives students a platform to discuss and debate nuclear issues such as the responsibility of nuclear engineers to protect the public from

nuclear misuse, or to report any wrongdoing or the dilemma of following-orders rather than applying regulations and best standards.

Another important course is an introductory course about nuclear energy that does not require any technical prerequisite. The course gives new students the opportunity to interact with the department in their first or second year of admittance, it also expose students to the historical and current development of nuclear energy at an early stage of their education, which helps them make an informed decision about their specialty choice.

The undergraduate curriculum leading to the Bachelor of Science (B.Sc.) in Nuclear Engineering, consist of a 159 Cr. Hrs. Students aspiring for a B.Sc. degree in Nuclear Engineering must successfully complete the 159 credit hours that are required to obtain the B.Sc. degree, these requirements are summarized in Table 4.

Table 2. Faculty and students numbers of the nuclear engineering department

Academic year	Number of students		Faculty number	Student to faculty ratio	NE Cr. Hrs. taught*
	Admitted	Enrolled			
2006/2007	20	20	1	20	0
2007/2008	37	57	2	29	9
2008/2009	33	90	3	30	19
2009/2010	27	117	4	29	44
2010/2011	20	130	5	26	66
2011/2012	15	126	3	42	66
2012/2013	17	112	3	37	66
2013/2014	23	112	4	28	66
2014/2015	n/a	n/a	6	n/a	66

**NE Cr. Hrs: the number of nuclear engineering credit hours taught by the nuclear engineering department each academic year*

Table 3. Nuclear engineering program courses distribution by specialty area

Nuclear specialty field	Credit hours	Lecture hrs/wk-sm	Laboratory hrs/wk-sm	Facilities available
Nuclear engineering & science basics	8	8	0	
Radiation and its applications	5	3	6	yes
Safety and radiation protection	6	5	3	TBE
Thermal hydraulic and heat transfer	3	3	0	
Reactor engineering and neutronics	10	7	9	yes
Nuclear system analyses and control	6	6	0	
Nuclear materials and Fuel Cycle	9	8	3	TBE
Modeling and design	9	8	3	yes
Applied engineering & capstone project	8	8	0	
Total Hours	64	56	24	
Total actual hours over five years	1024	896	384	

Hrs/wk-sm are the actual instruction hours per week per semester the student receives; semester is 16 weeks of instruction; laboratory facilities available or to be established (TBE) in the future

Table 4. Credit hours (Cr. Hrs.) required to obtain a bachelor of science (B.Sc.) degree in nuclear engineering

	Mandatory Cr. Hrs.	Electives Cr. Hrs.	Total Cr. Hrs.
University Requirements	16	9	25
College of Engineering Requirements	32	0	32
Nuclear Engineering Department Requirements	64	10	74
Other Engineering Department Requirements	28	0	28
Total	140	19	159

3.2 Facilities

Since its inception, the department planned to be equipped with all necessary laboratories and facilities that support the curriculum and which offer students a hands-on experience in basic nuclear engineering fundamentals. Although laboratories to support safety, radiation protection, materials and fuel cycle are still needed, the following laboratories that support the rest of the curriculum were established in the nuclear engineering department:

3.2.1 Radiation detection and measurement laboratory

This basic radiation science laboratory exposes students to experiments in nuclear electronics, radiation detection, gamma spectroscopy, radiation survey, radiation attenuation and shielding. The laboratory supports the curriculum courses in radiation and its applications.

3.2.2 High speed parallel computational laboratory

This is a computer cluster consisting of 96 processors that enable student to perform parallel computation of nuclear engineering problems and to run design and simulation exercises of nuclear systems via a Virtual Private Network (VPN). This allows the student to connect to the cluster and use its resources, with his/her personal computer from any place. The laboratory supports the modeling and design courses.

3.2.3 Subcritical reactor laboratory

This is a small reactor designed to provide nuclear engineering students with practical training in nuclear fission process, in a safe laboratory setting and with minimum exposure to radiation, it is one of the most effective tools for educating and training. Its simple construction (Fuel & Moderator) in an open tank, allows students to modify core configuration, work very close to the core, observe and see every part of the reactor and obtain a clear physical picture of the basic features of a reactor in a way that is impossible in power or research reactors.

Students are able to perform of the basic nuclear reactor experiments [12] such as; approach-to-criticality experiment, axial and radial flux distribution measurement, absolute flux measurement, Rossi-α method, Feynman-α method, source-jerk experiment, fuel void effect, and control rod (poison) effect. The control room of the subcritical reactor is made to resemble that of a nuclear reactor control room, as to familiarize students and trainees with reactor control environment and setting, as shown in Fig. 2 [12]. The laboratory supports the required reactor engineering and neutronics courses.

4. STUDENTS

The education program is designed to fulfill Jordan's needs for nuclear engineers and scientists, thus the students populace and department size was set to remain within the boundaries that serve this purpose [14].

In view of the fact that Jordan does not have any nuclear industry, the department vision was to maintain the number of students at about 100 for the first ten years, thus accepting 20–25 new students every year (Fig. 3), such a small program size would have many advantages:

1. It will help all graduates in having a job opportunity, for the next ten years based on current market needs for Jordan
2. It will help the department in keeping a competitive edge, by attracting the best students to the program
3. It will ensure that most graduates will be employed, even in the worst case scenario where Jordan does not go forward with its nuclear power program [14].
4. The student to professors ratio would be maintained at an acceptable level [14].

Since its inception, the department succeeded in attracting the best students with A averages, in its first year students admitted to the program were from the top 5% of secondary school graduates. This was made possible by public awareness and the infatuation of Jordanians for science and technology education in general.

The positive public acceptance of the nuclear program did not last long and it took a nosedive in 2012, following years of empty promises, disinformation, mismanagement and corruption allegations against Jordan atomic energy commission, that resulted in a parliamentary vote to suspend the nuclear program [13].

The first nuclear engineering class of 19 students graduated in 2011, this was followed by 30 students in 2012 and 23 students in 2013. Making the total nuclear engineering department graduates 72 students, 70% of which are male and 30% are female, the annual number of graduates is illustrated in Fig. 4. [9]

Fig. 2. The control room of the subcritical reactor laboratory at the nuclear engineering department in Jordan

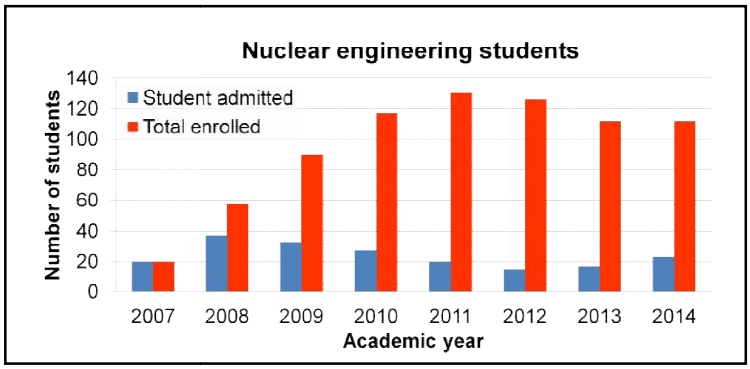

Fig. 3. Number of students in the nuclear engineering department

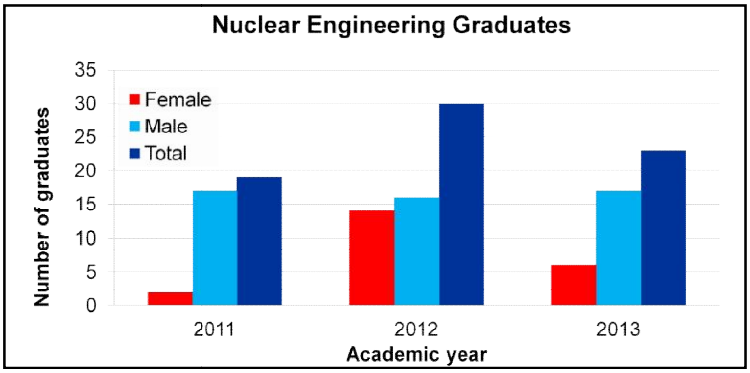

Fig. 4. Number of students that graduated with B.Sc. degree in nuclear engineering

5. CONCLUSION

In 2007 the first university nuclear engineering department was established in response to Jordan assertion that it plans to build a nuclear power plant by 2015. Recognizing the vital importance of nuclear knowledge in the successful and safe implementation of any nuclear power program, the department assumed the lead role of Jordan's human capacity building, by educating and graduating competent engineers that will help in designing, building, regulating and operating of Jordan's first nuclear power plant. Over the past seven years the university has graduated a total of 72 students with a Bachelor of Science degree in nuclear engineering, 50 males and 22 females.

The department was designed to fulfill Jordan needs for nuclear professionals; thus the

curriculum focus was on nuclear fission reactors rather than a comprehensive nuclear science and technology, the students populous was also maintained at a level to serve that propose. In light of the continuous postponement of the nuclear power plant building date from 2015 to 2017, 2019, 2020, in addition to public rejection and corruption allegations of the country nuclear program [13], it is recommended that the nuclear engineering education plan be revised and updated to include nuclear sciences, health physics and fusion.

Staffing the department with high caliber faculty based on academic excellence, rather than cronyism remains to be a big challenge, particularly in light of the mismanagement that the whole nuclear program in Jordan has witnessed.

Nuclear engineering is a very specialize education and training field which must adhere to the highest international standards, especially that graduates might end up working worldwide in a zero tolerance industry.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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