

1 **Original Research Article**
2 **The Engineering of an Undergraduate Nuclear**
3 **Education Program in Jordan**

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5
6 **ABSTRACT**
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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 at 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.

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9 Keywords: nuclear engineering, education, Jordan, human resources, university, JUST

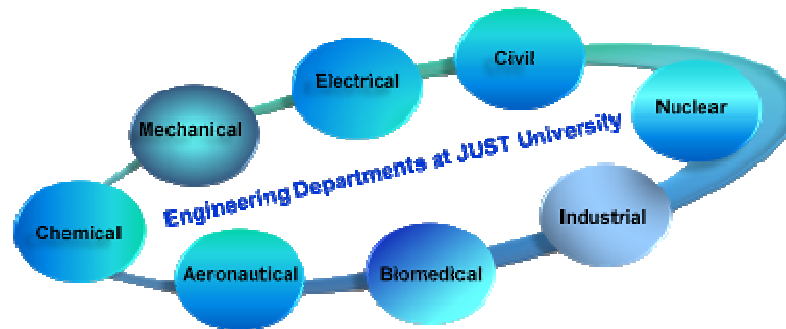
10 **1. INTRODUCTION**
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12 In 2007 the world witnessed an unprecedented number of countries expressing their interest
13 or declaring their intention to peruse a nuclear power program for the first time. The vast
14 majority of the 65 countries that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

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

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

32



33

34 **Figure 1. Engineering departments at Jordan university of science and technology**
35

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

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

43 **Table 1. Number of professors and rank of the teaching faculty at the College of**
44 **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

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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.

The enormous challenge that will face the university will be staffing the department with such high caliber 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, 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, 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.

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

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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].

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

79 Currently 50% of the faculty members are from the same family as the university president
80 [8]. In fact, the majority of students sent by the university to study abroad were from that
81 same family, which raises the question if the criterion was academic excellence or kinship
82 and cronyism. The lack of integrity and equal opportunity will undermine any education
83 system, and will definitely affect not only nuclear engineering education but also the safety
84 and security of the whole nuclear program in Jordan.

85 3. THE EDUCATIONAL CURRICULUM

86 3.1 Courses offered by JUST

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

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

100 **Table 3. Nuclear engineering program courses distribution by specialty area**

Nuclear specialty field	Credit Hours	Lecture Hrs/ wk-sm	Laboratory Hrs/ wk-sm
Nuclear engineering & science basics	8	8	0
Radiation and its applications	5	3	6
Safety and radiation protection	6	5	3
Thermal hydraulic and heat transfer	3	3	0
Reactor engineering and neutronics	10	7	9
Nuclear system analyses and control	6	6	0
Nuclear materials and Fuel Cycle	9	8	3
Modeling and design	9	8	3
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

101

102 The curriculum features an important course that distinguishes it from most nuclear
 103 education programs worldwide [11] “Ethics and the introduction of nuclear energy”, is a
 104 course that introduces students to the ethical responsibilities that accompany working with
 105 nuclear energy. It also gives students a platform to discuss and debate nuclear issues such
 106 as the responsibility of nuclear engineers to protect the public from nuclear misuse, or to
 107 report any wrongdoing, or the dilemma of following orders rather than applying regulations
 108 and best standards.

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

114 **Table 4. Credit hours (Cr. Hrs.) required to obtain a Bachelor of Science (B.Sc.)**
 115 **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	64	10	74
Other Engineering Department	28	0	28
Total	140	19	159

116

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

121 **3.2 Facilities**

122 Since its inception, the department planned to be equipped with all necessary laboratories
 123 and facilities that support the curriculum, and which offer students a hands-on experience in
 124 basic nuclear engineering fundamentals, the following laboratories were established in the
 125 nuclear engineering department:

126 **3.2.1 Radiation Detection and Measurement Laboratory:**

127 This is a basic radiation science laboratory that exposes students to experiments in nuclear
 128 electronics, radiation detection, gamma spectroscopy, radiation survey, radiation attenuation
 129 and shielding.

130 **3.2.2 High Speed parallel computational Laboratory:**

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

135 **3.2.3 Subcritical Reactor Laboratory:**

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

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



149

150 **Figure 2. The Control Room of the** subcritical reactor laboratory at the nuclear
151 **engineering department in Jordan**

152 **4. STUDENTS**

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

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

- 160 1. It will help all graduates in having a job opportunity, for the next ten years based on
161 current market needs for Jordan
- 162 2. It will help the department in keeping a competitive edge, by attracting the best
163 students to the program

- 164 3. It will ensure that most graduates will be employed, even in the worst case scenario
 165 where Jordan does not go forward with its nuclear power program
 166 4. The student to professors ratio would be maintained at an acceptable level

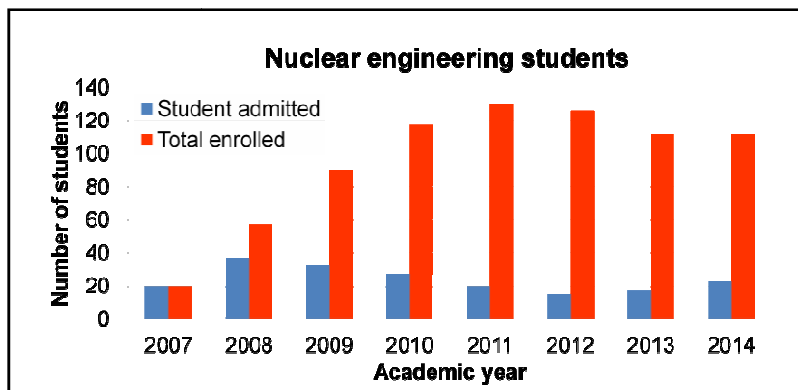


Figure 3. Number of students in the nuclear engineering department

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

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

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

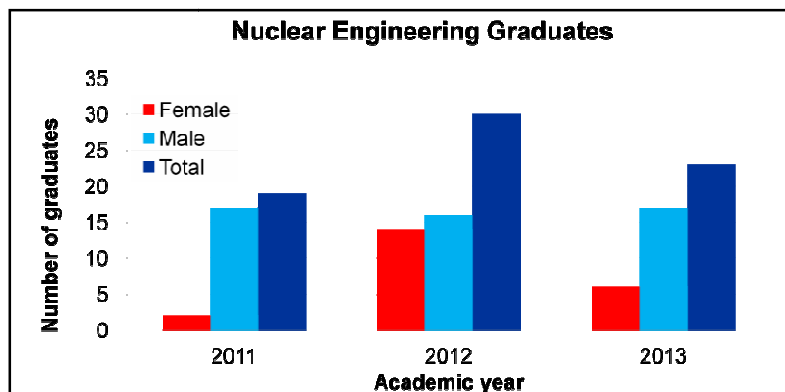


Figure 4. Number of students that graduated with BSc degree in nuclear engineering

5. CONCLUSION

In 2007 the first university nuclear engineering department was established in response to Jordan's 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's needs for nuclear professionals; thus the curriculum focus was on nuclear fission reactors rather than a comprehensive nuclear science and technology, the students' population was also maintained at a level to serve that purpose. 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's 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 specialized 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.

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