

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

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5
6 **ABSTRACT**
7

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.

8
9 Keywords: nuclear engineering, education, Jordan, human resources, university, JUST

10 **1. INTRODUCTION**
11

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 ~~Recognizing the vital importance of nuclear knowledge, and that human capacity building is~~
20 ~~the first step in the effective planning and implementation of a successful nuclear power~~
21 ~~program, In 2007, Jordan announced that Jordan plans to build and operate four nuclear~~
22 ~~power plants by 2015 [2, 3]. Recognizing the vital importance of nuclear knowledge, and that~~
23 ~~human capacity building is the first step in the effective planning and implementation of a~~
24 ~~successful nuclear power program, the nuclear engineering department was established at~~
25 ~~Jordan University of Science and Technology (JUST). Immediately after Jordan declared its~~
26 ~~intention to introduce nuclear power as part of its energy mix [2], the decision was made to~~
27 ~~establish a nuclear engineering education program.~~ The establishment of such a program
28 was the first step in Jordan's efforts to develop its nuclear infrastructure.

29 The nuclear engineering department at Jordan University of Science and Technology
30 (JUST), is the first and only such department/program in Jordan. **This** university itself is a
31 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 different** departments (Figure 1) and approximately 7,000 students [3], the college is staffed with 158 professors distributed over the departments as shown in Table 1. [4]

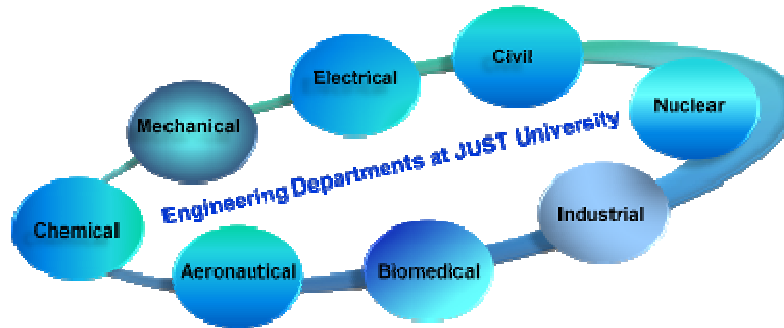


Figure 1. Engineering departments at Jordan university of science and technology

2. NUCLEAR ENGINEERING EDUCATION

~~In 2007 following the announcement that Jordan plans to build and operate its first nuclear power plant by 2015 [4], the nuclear engineering department was established at Jordan University of Science and Technology (JUST).~~

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).

~~The nuclear engineering department at Jordan university of science and technology is the first and only such department/program in Jordan.~~ 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].

Table 11. Number of professors and rank of the teaching faculty at the College of engineering departments

<u>Department</u>	<u>Full Professor</u>	<u>Associate Professor</u>	<u>Assistant Professor</u>	<u>Total</u>
<u>Aeronautical Engineering</u>	<u>0</u>	<u>3</u>	<u>2</u>	<u>5</u>
<u>Biomedical Engineering</u>	<u>2</u>	<u>2</u>	<u>5</u>	<u>9</u>
<u>Chemical Engineering</u>	<u>10</u>	<u>7</u>	<u>1</u>	<u>18</u>
<u>Civil Engineering</u>	<u>20</u>	<u>16</u>	<u>8</u>	<u>44</u>

Electrical Engineering	<u>15</u>	<u>8</u>	<u>9</u>	<u>32</u>
Industrial Engineering	<u>1</u>	<u>7</u>	<u>6</u>	<u>14</u>
Mechanical Engineering	<u>14</u>	<u>8</u>	<u>8</u>	<u>30</u>
Nuclear Engineering	<u>1</u>	<u>1</u>	<u>4</u>	<u>6</u>
College Total	<u>63</u>	<u>52</u>	<u>43</u>	<u>158</u>

2.2 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 enough 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 the preferred method of 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 other disciplines would remain poor in nuclear engineering since they missed most of the basic and fundamental education in that field.

Table 223. Faculty and students numbers of the nuclear engineering department

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

78

2014/2015	n/a	n/a	6	n/a	66
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79 The department started in the year 2006/2007 with one professor, and has grown to have six
80 professors in the year 2014/2015. The number of faculty have fluctuated randomly as a
81 result of administrative decisions, and not necessarily based on the department needs. As
82 can be seen in Table- 32, in the year 2011/2012 the department had 127 students and
83 merely 3 teaching faculty members, resulting in a the highest student to faculty ratio (of 42:1)
84 over the last nine years. [98, 119]

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

89 Currently 50% of the faculty members are from the same family as the university president
90 [98]. In fact, the majority of students sent by the university to study abroad were from that
91 same family, which raises the question if the criterion was academic excellence or kinship
92 and cronyism. The lack of integrity and equal opportunity will undermine any education
93 system, and will definitely affect not only nuclear engineering education but also the safety
94 and security of the whole nuclear program in Jordan.

95

96 **32.1 THE EDUCATIONAL CURRICULUM**

97 **3.1 Courses offered by JUST**

98 The curriculum was designed to focus on nuclear power engineering, in particular nuclear
99 power from fission reactors. It is intended to educate students in the basics of nuclear
100 technology, radiation measurement, and power reactor engineering; furthermore, it gives the
101 student a very strong background in basic sciences and engineering. The nuclear
102 engineering compulsory courses courses distribution base on their specialty area are is
103 tabulated in Table- 13, the 64 credited hours are distributed between 56 Cr.Hrs. for lectures
104 and 8 Cr.Hrs. for laboratory. Thus over five years, the student receives 896 actual classroom
105 hours and 384 actual hours in the laboratory, totaling 1024 hours of compulsory nuclear
106 education. .

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

112 **Table 331. Nuclear engineering program courses distribution by specialty area type**

Courses-Type	Lecture-Cr. Hours	L a b C r .	Total Cr. Hrs.	%

		H o u r s		
Humanities	24	1	24	15.7%
Basic Sciences	30	2	32	20.2%
General Engineering Sciences	25	4	29	18.2%
Nuclear Engineering Sciences	63	10	73	45.9%
Total	142	17	159	100%

<u>Nuclear specialty field</u>	<u>Credit Hours</u>	<u>Lecture Hrs/ wk-sm</u>	<u>Laboratory Hrs/ wk-sm</u>
<u>Nuclear engineering & science basics</u>	<u>8</u>	<u>8</u>	<u>0</u>
<u>Radiation and its applications</u>	<u>5</u>	<u>3</u>	<u>6</u>
<u>Safety and radiation protection</u>	<u>6</u>	<u>5</u>	<u>3</u>
<u>Thermal hydraulic and heat transfer</u>	<u>3</u>	<u>3</u>	<u>0</u>
<u>Reactor engineering and neutronics</u>	<u>10</u>	<u>7</u>	<u>9</u>
<u>Nuclear system analyses and control</u>	<u>6</u>	<u>6</u>	<u>0</u>
<u>Nuclear materials and Fuel Cycle</u>	<u>9</u>	<u>8</u>	<u>3</u>
<u>Modeling and design</u>	<u>9</u>	<u>8</u>	<u>3</u>
<u>Applied engineering & capstone project</u>	<u>8</u>	<u>8</u>	<u>0</u>
<u>Total Hours</u>	<u>64</u>	<u>56</u>	<u>24</u>
<u>Total actual hours over five years</u>	<u>1024</u>	<u>896</u>	<u>384</u>
—Hrs/wk-sm are the actual instruction hours per week per semester the student receives.			
* * Semester is 16 weeks of instruction			

113

114 The curriculum features an important course that distinguishes it from **any other most**
 115 nuclear **education** programs worldwide [118] “Ethics and the introduction of nuclear energy”,
 116 is a course that introduces students to the ethical responsibilities that accompany working
 117 with nuclear energy. It also gives students a platform to discuss and debate nuclear issues
 118 such as the responsibility of nuclear engineers to protect the public from nuclear misuse, or
 119 to report any wrongdoing, or the dilemma of following ~~—~~orders rather than applying
 120 regulations and best standards.

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

Table 442. Credit hours (Cr. Hr.) required to obtain a Bachelor of Science (B.Sc.) B.Sc. Degree in nuclear engineering

	Mandatory Cr. Hr.	Electives Cr. Hr.	Total Cr. Hr.
University Requirements	16	9	25
College of Engineering Requirements	32	0	32
Nuclear Engineering Department	6064	1410	74
Other Engineering Department	28	0	28
Total	136140	2319	159

The undergraduate curriculum leading to the Bachelor of Science (B.Sc.) in Nuclear Engineering, consists of a 159 semester-Credit Hhours (Cr.Hr.). Students aspiring for a B.Sc. degree in Nuclear Engineering must successfully complete 159 credit hours, which that are required to obtain the B.Sc. degree in Nuclear Engineering, these requirements are summarized in Table 42.

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, the following laboratories were established in the nuclear engineering department:

3.2.1 Radiation Detection and Measurement Laboratory:

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

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 vpn terminals.

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

157 measurement, absolute flux measurement, Rossi- α method, Feynman- α method, source-jerk
158 experiment, fuel void effect, and control rod (poison) effect.



159

160 **Figure 2. Subcritical reactor laboratory at the nuclear engineering department in**
161 **Jordan**
162

163 **2.2 Faculty**

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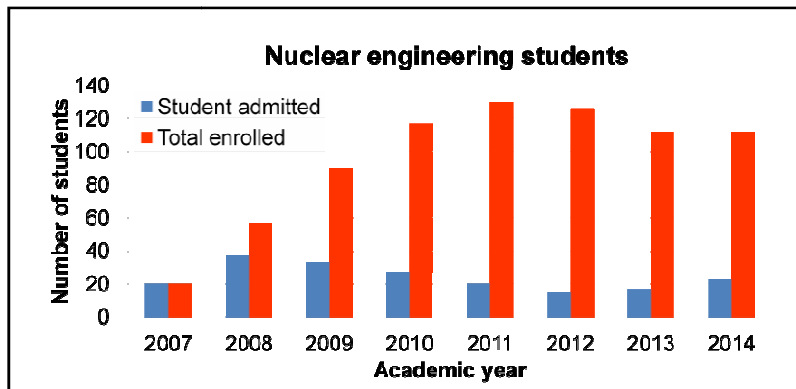
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197 **42.3. STUDENTS**

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

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

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



212 **Figure 23. Number of students in the nuclear engineering department**

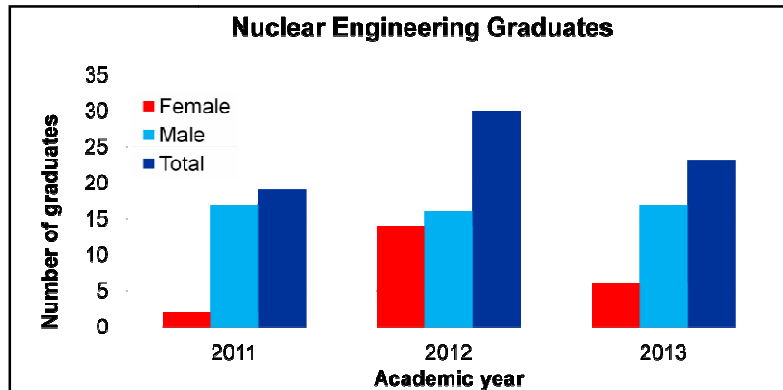
213

214

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

219 The positive public acceptance of the nuclear program did not last long, and it took a
 220 nosedive in 2012, following years of empty promises, disinformation, mismanagement, and
 221 corruption allegations against Jordan atomic energy commission, that resulted in a
 222 parliamentary vote to suspend the nuclear program [130].

223 The first nuclear engineering class of 19 students graduated in 2011, this was followed by 30
 224 students in 2012 and 23 students in 2013. Making the total nuclear engineering department
 225 graduates 72 students, 70% of which are male and 30% are female, the annual number of
 226 graduates is illustrated in [Figure 4figure-3](#). [119]



227
 228 **Figure 43.7** Number of students that graduated with BSc degree in nuclear engineering
 229

230 **52.4. Facilities**

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 253 ~~experiment, fuel void effect, and control rod (poison) effect.~~



Figure 4. Subcritical reactor laboratory at the nuclear engineering department in Jordan

4. 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 (BSc.) 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 [139], 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~~ end up working worldwide in a zero tolerance industry.

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