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Curriculum Development of a Nuclear Engineering Course for Human Resources Enhancement in the Kenya Nuclear Energy Program

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1. Abstract

In order to increase generation capacity from reliable sources, Kenya has proposed to install a low-end nuclear power plant to supplement the envisaged short fall. At the moment, most of the power is generated from hydro and geothermal sources. Although an expansion of geothermal and renewal energy may provide a solution to meet the demand, the advantages of nuclear energy are still regarded as attractive. The success of the proposed program will be dependent on the availability of a well trained manpower. This can initially be sourced as part of the turnkey project but the development of a local training institute would provide higher sustainability. It is for the reason the University of Nairobi has been identified to offer a nuclear engineering degree course. The challenges and proposed solutions are presented in this paper.

2. Introduction

The demand for more energy generation has arisen due to the economic growth. There is need for a reliable energy supply at competitive prices. The current situation in Kenya is heavily reliant on hydro and thermal sources. The total installed capacity is 2200MW of which 820MW is from hydro sources, 588MW from geothermal, 717MW from thermal and 25MW from wind and 26MW from co-generation. A 55MW solar plan and a 300MW wind plant are under construction. The plan is to rely less on hydropower due to reduced and unpredictable rainfall pattern. The drive also involves a sustainable development that has to reduce the dependence on fossil fuel such as heavy oil and coal. The drive for cheap energy and less carbon emission has led to the proposal to construct a 1000MW nuclear power plant. This requires the formation of appropriate legal and regulatory frameworks. It also requires the training of specialized manpower to handle operation and management and safety measures as well as linkage to international regulators. This is the view held by Choi et al [1] that the building of human resources precedes the Plant implementation.

One of the areas of public concern is the issue of safety in the power plant operation, and in spent fuel transportation and disposal. These fears have been enhanced by the incidences of the three-mile island in Pennsylvania, Chernobyl disaster in the former Soviet Ukraine and recently in Fukushima. It is only by producing well trained staff and adherence to regulations that the public acceptance of nuclear energy could be obtained. In this regard, the program to train Nuclear Engineers must clearly be seen to answer these concerns. In this paper, we present the outline of the proposed curriculum and identify the key challenges that have to be met.

The rest of the paper is arranged as follows. In section 3, the current status in the University of Nairobi is presented. The tree university units that will be involved in the proposed nuclear engineering program are briefly discussed. In section 4, the curriculum design philosophy is presented. In section 5, the proposed curriculum is presented and discussed. The issue of benchmarking is briefly discussed in section 6. The concluding remarks are made in section 7.

3. Current Status

The School of Engineering in the University of Nairobi has well established departments of Electrical Engineering and Mechanical Engineering. These two, in addition to the Institute of Nuclear Science and Technology will serve as a catalyst to spur the formation of a nuclear engineering program. The Electrical Engineering department has suitable equipment and well trained staff in Electrical Power generation, Control Systems, Applied Electronics and in Instrumentation. Likewise, the Mechanical Engineering department has staff specialized in Thermofluids, Materials and in Machine design. The Institute of Nuclear Science and Technology has some specialists in radiation detection and protection and also in environmental pollution. The facilities in these three units can be used to support the peripheral units in Nuclear Engineering. However, there are no specialists in the core nuclear engineering areas such as reactor physics, nuclear fuels and in many other important sub-areas.

The aim to introduce a Nuclear Engineering curriculum at the Bachelor degree level. The contents are be formed by the main objective of producing graduates who could be engaged not only in Nuclear power plant operations and maintenance but also in allied area such as radiation detection and protection, regulation and medical applications. The curriculum is also expected to satisfy both local and international accreditation bodies. The major challenges in launching the curriculum are manpower, training equipment and student attachment to industry. These are discussed below.

3.1 Manpower

In the absence of qualified staff to teach the core units, a linkage with established institutions may be the only way to address the problem. A close academic linkage with Korean Universities has been proposed. A Kenyan team has already visited the following universities:

(i) Seoul National University
(ii) Hanyang Univeristy
(iii) KAIST
(iv) KINGS

All these institutions have well established Nuclear engineering programs and have expressed willingness to work with the University of Nairobi. This will be through a Memorandum of Understanding through the Korea Nuclear Association. Under such linkage it will be possible to invite Korean Professors to Kenya for short term visits to assist in the teaching of the core units in the program. The Universisiti Tenaga Malaysia has adopted a similar strategy with the Texas A&M university[2]. In addition to such visits, we have several Kenyan students who are training in Nuclear Engineering in Korean Universities at undergraduate and post-graduate levels under the sponsorship of the Kenya Nuclear Authority. Some of the graduates are expected to eventually join as academic staff to teach the proposed program.

The linkage can also provide access to teaching material and software resources. It is also through such linkages that external examiners of the program can be sourced. This is also an important component of benchmarking and quality assurance.

3.2 Training Equipment and student attachment

The teaching of Engineering courses require adequate support in terms of experimental work and industrial exposure. This serves to extend the theory that is covered in lectures and also prepares the students for familiarization with future equipment, procedures and processes. The proposed nuclear engineering course will be heavily supported by the Kenya Nuclear Authority in the purchase of suitable laboratory equipment that closely relates to the type of plant that is to be installed. This will also involve the training of staff to handle and operate the equipment. The practical exposure and internship shall be realized by attaching students to nuclear facilities for short durations. Since the country has no nuclear facilities, co-operation with the KNA would be useful in ensuring such possibilities. This is a key part in the Nuclear engineering training program and success may depend on the availability of such opportunities.

4. The Curriculum Design Philosophy

The International Atomic Energy Agency (IAEA) has issued suitable guidelines for the design of an Nuclear Engineering program [3]. These guidelines are flexible and easily modified to suit the need of a particular country. It reinforces the knowledge of Mathematics, Physics and Chemistry as the foundation of a good Nuclear engineering program. It further identifies some general and some specific competences that should be acquired by a nuclear engineering graduate. We have identified the following general competences to be suitable in the proposed program.

(i). Good written and oral communication
(ii). Effective participant in group work
(iii) An excellent understanding of the basic laws of Science

The Specific competences that have been included in the program enable the graduate to:

(i). Perform radiation protection measurements and analyze the results
(ii). Participate in the design process of principal system and components of a nuclear power plant
(iii). Have an excellent understanding of safety procedures and human limitations.

The program will have course units that deliver and test these competences and all levels.

5. The Curriculum

The curriculum entrance level is aimed at high school graduates who have completed the equivalent of the 12^{th} grade in the US system of education or ''O" levels in the British System of education. The program will have a duration of 5 years in order to satisfy the requirements of the Engineers Board of Kenya which is the national accreditation agency. Each year has two semesters of 16 weeks each. The delivery of the course is by lectures, continuous assessment tests, semester exams, laboratory experiments, field visits, workshop practice, industrial attachment and supervised final year projects. The course units in the program are discussed below.

5.1 First Year of Study

In the first year of study, the course units will be taken in common with other engineering programs. This also offers the foundation for the sciences and introduces the students to the nuclear engineering profession. In conformity with university requirements, the course unit in Health Education is to be offered at this level. A list of the units is given in Table I.

Table I: First Year Course Units

First Semester	Second Semester
Physics	Physics
Pure Maths	Pure Maths
Applied Maths	Applied Maths
Chemistry	Chemistry
Introduction to Nuclear Eng	Communication skills
Computer Science	Health Education

5.2 Second Year of Study

In the second year of study offers a diversity of course units in Mechanical and Electrical engineering areas as well as atomic and nuclear physics. The course unit in Engineering Drawing is also offered at this level. The Workshop Technology unit is meant to introduce the students to tools and procedures related to electrical and mechanical engineering practice. The proposed course units are listed in Table II.

Table II: Second Year Course Units

First Semester	Second Semester
Linear Algebra	Ordinary Differential Equ
Atomic Physics	Nuclear Physics
Computer Science	Thermodynamics
Electric Circuits	Electronics
Material Science	Mechanics of Machines
Engineering Drawing	Workshop Technology

5.3 Third Year of Study

In the third year of study, more units in nuclear engineering are introduced. This includes core units like Radiation Detection and Protection and Reactor Theory. All the units are given in Table III.

Table III: Third Year Course Units

First Semester	Second Semester
Numerical Methods	Statistics
Electrical Machines	Control Systems
Fluid Mechanics I	Fluid Mechanics II
Radiation detection	Radiation protection
Economics for Engineers	Heat Transfer
Reactor Theory I	Reactor theory II

5.4 Fourth Year of Study

In the fourth year of study, the course units are mainly in the core areas of Nuclear Engineering. The Reactor design units are to be presented in a depth that will enable the graduates of the program to be useful in the nuclear power plant practice and safety. All the units are shown in Table IV. After the end of the fourth year, an 8-week industrial attachment is recommended.

Table IV: Fourth Year Course Units

First Semester	Second Semester
Partial differential equ	Reactor instrumentation
Reactor design I	Reactor Design II
Nuclear Materials	Nuclear fuel cycle
Radiation Interaction	Radiation Shielding
Nuclear power plants	Waste Management I
Reactor thermal hydraulic	Engineering Management

5.5 Fifth Year of Study

In the fifth year of study, advanced units in nuclear engineering will be offered as well as Management and case studies. Each student will be assigned an engineering project under the guidance of a member of staff. The project extends to two semesters and is expected to train the student in design as well as in research methods. The course units for the fifth year course are listed in Table V.
In the final year of the course, optional units will be on offer. These will be dependent on contemporary topics and on areas of research of interest to staff members.

Table V: Fifth Year Course Units

First Semester	Second Semester
Optimisation	Waste Management II
Regulation & Licencing	Probabilistic risk analysis
Decommissioning	Case studies: Accidents
Engineering project	Engineering Project
Options	Options

6. Benchmarking

The proposed program has to be benchmarked with others offered in different countries. The bench marking metrics are among those recommended by IAEA [1]. Among these metrics, three have been identified as the most urgent. These are:

(i). Capacity to deliver the program
(ii). Collaboration with industry
(iii). Human resource policy
(iv). Professional accreditation

The university has well established benchmarking procedures that have been used for the existing Engineering programs. These will be translated to include the proposed nuclear Engineering program.

7. Conclusions

We have presented a proposed curriculum in Nuclear Engineering that aims to development human resources that would be useful in driving the Kenya Nuclear Power generation strategies. The challenges in the program can be resolved by building linkages with established Universities in Korea under the assistance of the Korea Nuclear Association.

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