The Need for Adapting Engineering Education: Preparing Engineering Students for New Employment Environments a.k.a. Nuclear Power

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Abstract - This paper describes the identification of the underpinning needed principles identified through meetings with the constituents. The review of the preparation needed from traditional engineering disciplines, new topical needs, and new levels of course materials identified as necessary to support the approach are also presented. The fundamental building block of this approach is the belief in the sound preparation of an "engineer" from which the necessary "add-ons" in knowledge are provided to round-out the students' preparation for entering the chosen area. This concept for nuclear power is applicable across "traditional engineering disciplines" as well as to other evolving technological areas as long as engineering fundamentals are strongly emphasized. The University of Tennessee at Chattanooga (UTC) is implementing this approach because it is located in the center of an evolving nuclear industry with such entities as TVA, Alstom TurboGenerator Group, and Westinghouse.

Keywords: engineering education, nuclear power, new employment environments

INTRODUCTION

When one looks at the field of engineering there appears to be a significant diversity and increasingly greater numbers of specialties within the traditional fields of Engineering: those being Civil, Chemical, Electrical, Mechanical, and Industrial. This has occurred for numerous reasons not withstanding the complexity of our increasingly sophisticated and technological society. The knowledge and understanding that are being gained accelerates the capabilities to advance and address more complex problems which are upon society.

These circumstances place new demands and strains on the engineering educational network to prepare the engineering graduate for entry into the workforce and to make contributions. With the accelerating knowledge base and engineering specialties, pressure is placed on the educational environment to adapt and provide these graduates. Yet what is the curriculum of the "engineering student?" Does it encompass that base components that all learn from time in memoriam plus the accumulated knowledge since that time? Does it respond timely to needs for an educated workforce in new or revived engineering specialties? How does the demand for resources in a tightening resource availability environment factor in? One approach is to define critical elements or fundamentals for the engineering student to become an engineer and then craft supplemental curriculum to meet the workplace knowledge needs. This approach must include defining where resources are available to support the learning.

DEFINING THE NEED

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The approach taken can be illustrated through a case analysis and curriculum development process. The particular case of a growing need of "nuclear" engineers to support a reviving engineering specialty is in the nuclear power field. For several decades, the nuclear power industries has been stagnant and limited to the existing nuclear power units and the military needs. In fact, the military has been a valued source of trained personnel who have entered the nuclear power industry. The recent increase of a revival of the nuclear power industry has spurred an increase in the need for engineers to support this while the pipeline for "nuclear engineers" has been sparse over the years.

So the question becomes how to meet the basic needs of the nuclear power industry for the engineering graduate as this renaissance is occurring. (This is evidenced by the nearly 20 new reactor units in the beginnings of the regulatory process.) The question must be segmented into two questions "What does the engineering graduate or recent graduate need to know to function and support this industry?" Secondly, "What is the curriculum for training a "nuclear engineer" and supporting resource needs?" An added consideration is "Why have the nuclear trained military personnel been of such support to the nuclear power industry?"

By reviewing the various organizations involved in the nuclear power industry and their respective functions, insight can be gained in regards to knowledge and educational needs for their new engineering hires. This is illustrated by broad industrial sector reviews. The sectors considered are the nuclear steam system supplier (NSSS), architect and engineer (A&E) including constructor, operator, licenser and regulator, and fuel supply and manager. The overall review must be balanced by the nature of the technology and application (in this case the energy source), regulatory environment, and public (societal) views and perceptions.

The review and analyses of the engineering requirements of the above sectors to support the revival of the nuclear power industry and its continuing operation lead to defining the educational needs for an engineering student desiring to enter the field. These educational needs recognize the technology specific characteristics, fundamental engineering specifics, significance of industry partnerships, understanding of public and societal views, and continuing educational needs. This is contrasted with a "nuclear engineering" curriculum.

The distilling of these analyses, reviews and considerations to their essence leads to defining the curriculum/educational needs. The essence is providing an engineering curriculum well-grounded in fundamentals with selected additions of technology-related courses which recognize the nature of the technology. The major need is for engineers grounded in the fundamentals with enhanced basic knowledge to function in the respective technical environments, i.e., most engineers at a nuclear power plant or in the supplier industry do not need to be "nuclear engineer" educated. The engineers need to understand the technology, its fundamentals, application, and how to function within its environment. This is the essence integrated with industrial partnerships and interaction. Again, the particular case of the nuclear power industry is used.

Addressing The Need

To address the need for the engineering graduate to enter the "nuclear field" and have the graduate with a "jump start," a curriculum is being embodied which resulted for the analysis described above. The fundamental conclusion is a graduate who is well-grounded in the engineering fundamentals is a core ingredient. To that basis, knowledge packets should be added which address the nature of the energy source, operational and control elements, unique instrumentation and measurement elements, materials and testing elements, regulatory and health elements, safety and safeguard elements, and simulation and modeling elements.

To incorporate the knowledge packets while remaining tractable, the necessary courses are framed from a system view of the nuclear power plant (and as an industry cycle) rather than any particular unit element. Industrial partnerships are utilized for off-campus laboratory experiences. For example, field visits to non-operating nuclear plant site and nuclear unit training simulators enable students to understand and experience the application of their learning in a non-academic environment. Similarly, on-site experience at national laboratories/installations will enable learning on modern nuclear instrumentation and equipment. A required semester internship at an approved nuclear facility (organization) is a requirement. The internship provides work experiences at actual commercial sites and application of the academic learning to actual utilization. Additionally, seminar presentations are utilized to the extent possible to incorporate practicing industry experts into the course curriculum.

The result of the above processes, identification of needs, and synthesis of elements has led to the defining of five courses which can be offered to engineering students to prepare them for functioning in the nuclear power industry as they graduate. The courses with brief topical description follow:

Introduction to Nuclear Power Engineering - Introductory course in nuclear power engineering. Neutron physics, reactor operation, and reactor dynamics. Basic principles underlying principles of design and operation of nuclear systems, facilities and applications. Topics include radioactivity, fission, fusion, reactor concepts, and effects of radiation, safety, and radioactive waste treatment. Nuclear and engineering principles of power reactors, emphasis of power reactors including power plant heat generation, and electricity generation. Students provided a system perspective and analysis of nuclear power engineering, associated fuel cycle, safety, and fundamental applications of nuclear energy.

Nuclear Instrumentation, Radiation Protection, and Health Physics - Instrumentation and supporting systems required for control and protection of a nuclear power plant. Radiation measurement, process measurement, and reactor operating principles used to develop instrumentation requirements and characteristics. Design and implementation issues include power supplies, signal transmission, redundancy and diversity, response time, and reliability. External and internal dosimetry, biological effects of radiation, radiation detection, and radiation risk assessment. Introduction to health physics and application of personal protection devices and monitoring.

Advanced Simulation and Modeling[2] - Introduction to advanced engineering simulation and modeling as analysis, and predictive techniques with a focus on application in the nuclear field. Reporting on internship. Report writing, communication, discussion. Use of computational techniques to solve engineering and engineering systems problems. The use of software packages, development of simulation models, and building relationship to physical experiences are incorporated. The lectures will provide an exposure to a range of application, based on the scientific exploitation of the power of computation across various disciplines. Basic knowledge necessary for intelligent simulation and interpretation of simulations of transients in nuclear power plants.

Advanced Materials Analysis and Application[3] - Properties and selection of materials for nuclear steam supply systems. Implications of radiation damage to reactor materials and material problems in nuclear engineering are discussed. An overview of crystal structure and defects, dislocation theory, mechanical properties, radiation damage, hardening and embrittlement due to radiation exposure and material problems. Analysis and application of materials to applications and use in industrial sectors beyond the nuclear industry. Techniques of joining and using advanced materials in the industrial sectors Mechanics techniques for components in plant systems, product applications, their functional purposes, with models of material behavior to determine adequacy of component design. Considerations include mechanical loading, brittle fracture, inelastic behavior, elevated temperatures, neutron irradiation, and seismic effects.

Risk Assessment, Standards, Regulations, and Safety - Operational and safety systems will be analyzed including engineered and passive safety features, transient response, and accident response. Current regulations and standards will be discussed. The application and use of probabilistic risk assessment will be explored and illustrated. Introduction to current regulations and standards including quality and design changes/modifications. Requirements/development of plant modification packages will be presented. Radioactivity releases internal and external to site and radioactive wastes handling and disposal.

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[2] Course title includes the word "Advanced…" at this point of time to distinguish the course as a separation course and as a follow-on course to prior coursework/components already studied by the student.

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Additional topics will be included such as licensing, fuel recycle, earthquake design, etc. Study of related topics such as globalization, environmental issues, guest speakers.

Table 1 provides a mapping of major nuclear engineering topics (courses) of a BS Nuclear Engineering program to knowledge packets contained within each of the five courses. The mapping also provides a relative measure of emphasis of each packet within the respective courses.

		Topic Packets Addressed in Respective Courses				
Major Nuclear Engineering Topics in BS program		**Intro. To Nuclear Pwr Eng**	**Instr, Rad Prot & Health Phys.**	**Adv. Simul. & Modeling**	**Adv. Materials and Appl**	**Risk Asst., Stds, Regs.**
Basic Definitions		@		*		@
Nuclear Physics		#	*			
Radiation, interaction w/matter, fission,			#		@	
Reactor Statics (Diffusion)		@				
Reactor Kinetics		#		#		
Reactor Dynamics		*				
Heat Transfer		#		#		
Thermal Hydraulics		#		#	#	
Reactor Design				@	*	
Instrumentation and Control		*	#		*	*
Operation and Maintenance				#	@	
Rad Detection, Meas., and Protection			@	*	*	
Health Physics and Rad. Safety			*			#
Nuclear Fuel Cycle		*				
Safety, Systems, Risk Assessment				@	@	@
Regs, Stds, & Lic.			@		*	@

KEY: @- Significant Packet Coverage, #- Fair Packet Coverage, * - Weak

Table 1. Mapping of Nuclear Enginee3ring Topics

A curriculum under "Engineering" has been developed to integrate these courses as a "Nuclear Power Option." The curriculum is heavily anchored in the fundamentals especially thermodymanics, heat transfer and fluids. The following Table 2 illustrates a typical curriculum employing the above concepts.

FRESHMAN	
First Semester	***Second Semester***
Basic Engineering Sci	Vector Statics
Basic E*F*ngineering Sci Lab	Intro to Engr Design
Rhetoric & Composition 1	Calculus 2
Calculus 1 & Lab	Elementary Linear Algebra
General Chemistry 1 & Lab	Rhetoric & Composition 2
SOPHOMORE	
First Semester	***Second Semester***
Physics E&M	Physics-Optics & Mod. Phys
Physics E&M Lab	Multivariable Calculus
Intro to Differential Equations	Intro Engr Computations
Mechanics of Materials	Electric Circuits 1
Mechanics of Materials Lab	Engineering Economy
Prob & Statistics Engineering	Fine Arts
Beh Soc Sci.	
JUNIOR	
First Semester	***Second Semester***
Control Systems	ME Thermodynamics
Control Systems Lab	Energy Conv & Electronics
Thermodynamics	ME Experimentation Lab
Fluid Mechanics & Lab	Heat and Mass Transfer
Engr Material Science	Intro. to Nuclear Power Engr.
Humanities	Nuc Inst. Rad Prot & Health[a]
SENIOR	
First Semester	***Second Semester***
Energy Conversion/Turbines	Adv. Materials Anal. & Appl.[c]
Thermal Component Design	Risk Asst., Stds. Regs. Safety[d]
Interdisciplinary Design I	Approved Elective
Adv. Simul and Modeling[b]	Interdisciplinary Design II[3]
Non Western Civ	Beh Soc Sci.

Table 2. Typical Curriculum-Nuclear Power Option

a. Includes combined laboratory exercises potentially as an intensive 1 to 2 week practical laboratory experience off-campus.

b. Analyzes pertaining to nuclear systems; reports and discussions from internship experience during summer of junior-senior year.

c Includes practical laboratory experiences addressing joining of materials techniques and methods.

d. All inclusive of topics addressing nuclear systems, standards, regulations, and safety requirements and issues.

e Interdisciplinary Design courses` will serve as design project if pertinent

This approach is not a necessity though: the courses are developed as a stand alone package. If any undergraduate engineering or suitably prepared student from another discipline selects these courses as electives or add-on courses, the student would obtain the same benefits.

A major benefit to this approach of defining and providing the student the necessary learning in a selected number of technology relevant courses allows the frequent adaptation of the engineering curriculum to new employment environments and skill demands. Furthermore, the course package (with enhanced and upgraded requirements) can permit ready application at the graduate level for the practicing engineers and/or recent graduate to prepare or train them for the new or evolving technical areas. Indeed, these courses have been adapted and upgraded for graduate delivery as a certificate program, electives for the Master of Science degree program, or offered as selected continuing education courses.

CONCLUSIONS

The systems view of a technology, its application, and societal impacts with the associated processes of examining the technology needs in terms of engineering talent and knowledge for the BS engineering graduate has permitted a technique to be developed which enables a “rapid” adaption in the engineering education environment to support needs. Simultaneously, it has evolved a method to deliver such knowledge and education needs to the practicing/recently graduate engineer. As a result of these efforts the following can be concluded.

- Engineering education can respond “quickly to new/evolving employment needs.
- Industrial relationships must be developed and maintained for adequate input and are an important sounding board.
- Laboratory and other facilities are available to the university in cooperation with the industrial partners at their sites.
- A pool of guest lecturers and instructors as available to the university through such industrial partnerships.
- Emphasis on rigorous education of the engineering fundamentals is a requirement.
- A selected package of courses which address key technology knowledge areas can be developed on a “timely” basis to provide engineers to meet evolving/new employment environments.
- The “graduating engineer” or practicing engineer is still a “traditional” engineer with a specialized skill set which is adaptable as technology changes.
- The selected packet of courses is readily adaptable to a graduate level for education needs.
- Selected topic areas within the course packet can be adjusted within this framework to meet specific needs of students or industries.

The current educational approach is now being implemented in the nuclear power option at UTC. Students are able to elect the “Nuclear Power” option or select the course as electives. A parallel graduate level packet (MS level) is being implemented as well to meet those identified needs.

REFERENCES

Author Note – The essentials topical elements of the nuclear courses portrayed here have been developed from input and review of several industry sources. Modifications to original course concepts resulted as presented the paper. Additional sources of background informational materials for traditional “BS Nuclear Engineering“ programs for selected universities were garnered from internet review of catalogs. These materials served as a backdrop for the nuclear 5 course program developed and presented here. The need for such an approach to educating engineers for the new environment in the nuclear industry is noted by the 20+ next generation nuclear reactor applications submitted to the federal government for consideration and initiation of licensing activities. To support such need will require fundamentally sound engineers with knowledge of nuclear power and not necessarily in-depth education as a “nuclear engineer.”

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