

## **AC 2007-1844: AN INNOVATIVE MECHANICAL AND ENERGY ENGINEERING CURRICULUM**

### **Efstathios Michaelides, University of North Texas**

Professor Stathis Michaelides is currently the coordinator of the Mechanical and Energy Engineering Program at the University of North Texas. He was previously (1998-2006) the Leo S. Weil Professor of Mechanical Engineering at Tulane University; Director of the South-Central Center of the National Institute for Global Environmental Change (2002-2006); Associate Dean for Graduate Studies and Research in the School of Engineering at Tulane University (1992-2003); Head of the Mechanical Engineering Department at Tulane (1990-1992); faculty member (1980-1990) and acting chair (1985-1987) of the Mechanical Engineering of the University of Delaware.

### **Reza Mirshams, University of North Texas**

Professor Reza Mirshams is Associate Dean of Engineering for Academic Affairs at the University of North Texas. Dr. Mirshams has degrees in Industrial Metallurgy and Metallurgical Engineering in the area of mechanical behavior of metals and alloys from the University of Birmingham, England and the University of Tehran. He is a Full Professor in the area of Materials Science and Engineering in the Engineering Technology with joint appointment in the Materials Science and Engineering Departments. He has been a Principal Investigator and Project Director for several engineering education grants for undergraduate research experience, a bridge and mentoring program, departmental curriculum reforms, and innovative interdisciplinary project oriented engineering education programs.

# **An Innovative Mechanical and Energy Engineering Curriculum**

## **Abstract:**

The continuing expansion of the new College of Engineering at the University of North Texas (UNT) has created an opportunity to establish a new Department of Mechanical and Energy Engineering and an excellent occasion for the establishment of innovative and interdisciplinary approaches to engineering education. The explicit addition of Energy to the Mechanical Engineering curriculum is a new model of engineering education that parallels the innovations of our current Learning to Learn (L2L) project oriented concept course with the addition of innovative approaches for mechanical engineering and emphasis on energy engineering education. The new Mechanical and Energy Engineering (MEE) baccalaureate-level program will provide the intellectual foundation for successful career preparation and lifelong learning for the students. This innovative curriculum has been designed with a system-level approach to ME-based design, on the fundamentals of undergraduate level energy engineering within the mechanical engineering discipline, and will provide experiential-oriented approaches for the better understanding of classical mechanical engineering principles. It will also provide a new interdisciplinary ME curriculum approach to the most important energy technology areas. We are going to present the curriculum and discuss components of the program from freshman to senior years. We expect that the graduates of this innovative undergraduate curriculum in Mechanical and Energy Engineering will have a unique educational experience with systems integration approach for addressing industrial challenges; working in interdisciplinary teams; and with cognitive learning experiences for responsible lifelong learning, in order to sustain creativity and productivity in their careers.

## **Introduction:**

The origins of human civilization are indelibly connected to the harnessing of energy in the form of fire: The caveman improved his and his clan's life by bringing fire (energy) into their caves/dwellings and using it for heating and cooking. Centuries later, the industrial revolution, which altered drastically the history and destiny of mankind, has its foundations in the harnessing of thermal energy by engines that produce mechanical work. Today, the wealth of modern nations and the welfare of their citizens depend greatly on the availability of affordable energy. Figures 1 and 2 that have been produced from data of the International energy Agency [1] show that the use of energy, either as total primary energy consumption or as electric power is directly correlated to both the affluence of a country and the longevity (which is equivalent to "better life") of its citizens.

As we progress in the twenty-first Century as a Nation, the availability of affordable energy is becoming a major challenge that imposes constraints in our economic growth. It is apparent, that we need to harness more efficiently our existing energy sources, to develop new energy sources and to better manage our ways of production, distribution and consumption of energy. At the same time we need to be conscious of the effects of energy production and consumption on the environment. We must ensure that our activities of today do not harm the Earth the next generations will inherit. The events of the last five years and the direction the world economies are taking show that there is a national need for more, better trained and environmentally

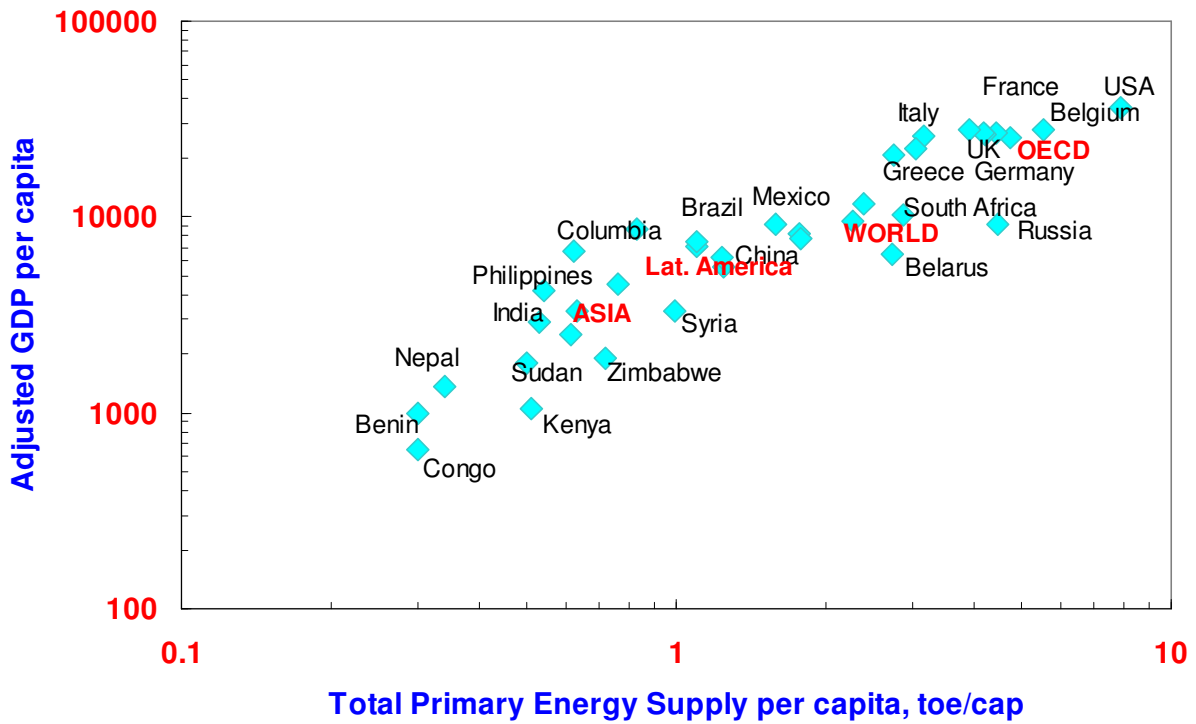


Figure 1. Purchase price adjusted GDP vs. primary energy supply per capita for representative countries. Group averages in red.

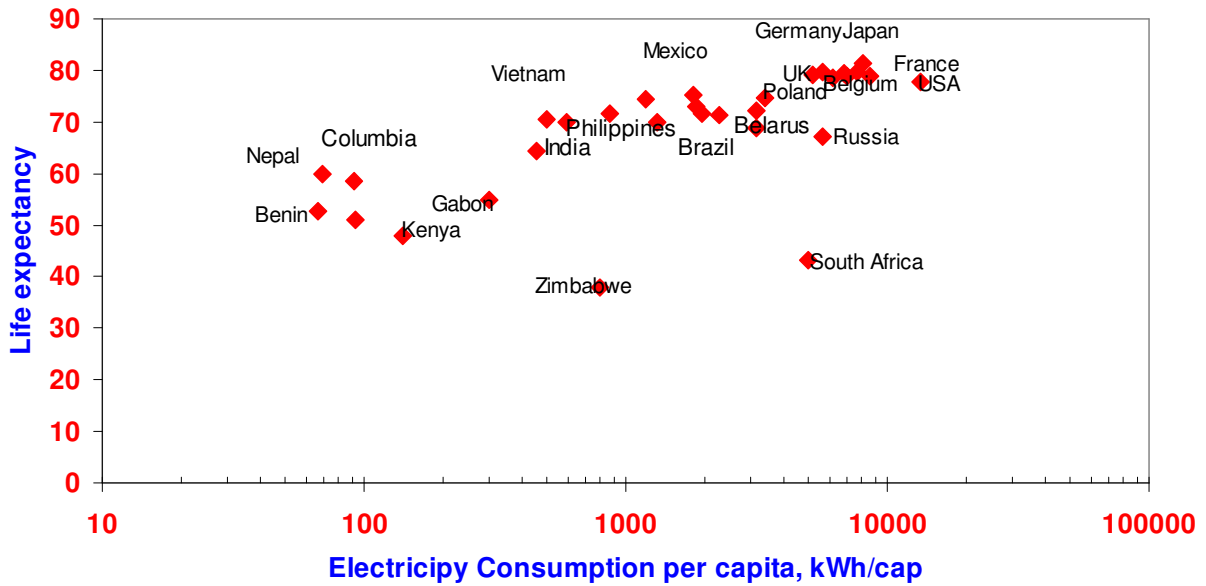


Figure 2. Life expectancy vs. electricity consumption per capita for representative countries.

conscious Energy Engineers who will tackle successfully the Energy Challenge and will assist the Nation and the World in meeting responsibly their energy needs. For this reason the University of North Texas has created a new Department of Mechanical and Energy Engineering that will educate and train Mechanical Engineers with a deep, fundamental knowledge and understanding of the Energy Challenge the world is facing. The Department will admit freshman students for Fall 2007 and three faculty and a department chair have been hired currently and a search for three new faculty in progress. Using innovative teaching methods, we will educate the modern Mechanical and Energy Engineer with a deep foundation of factual knowledge and strong experience in engineering methods and research. We intend to educate and train the engineer of the twenty-first Century, who will “think outside the box” and will create solutions to our Energy Challenge.

This short paper presents the curriculum that has been adopted by the faculty of the new Department of Mechanical and Energy Engineering. The curriculum has been designed to provide the students basic, fundamental knowledge of the Mechanical Engineering discipline with emphasis on the energy subjects that are elements of the discipline. Armed with this knowledge and the ability to learn by themselves, graduates of the program will be able to train themselves in the future, in order to master future technological developments, to be always well-informed in their subjects and to be productive throughout their professional careers.

## **Development of the Mechanical and Energy Engineering Curriculum:**

### **A. Constraints**

Even in the development of a new program faculty are not able to work in the development of a curriculum without external constraints. The most important constraint is that the program of study must be feasible to be completed by a full-time student within eight semesters. This has placed an upper limit of 125 to 135 hours on all Engineering curricula. In the case of the Mechanical and Energy Engineering Department at UNT, a few other constraints have been imposed from three institutions: the State of Texas; the University of North Texas itself; and, since it is desired that the new program is accredited, by ABET. In this case, the State of Texas requires of all publicly supported institutions of higher learning to include a “core curriculum” of forty-two credit hours consists of 36 credit hours required and 6 additional hours selected by the university among specified areas such as communication, wellness, cross-cultural and diversity, or any other institutional options. The specific areas of 36 credit hours are English (6 credits), natural sciences (6 credit hours), U.S. history (6 credit hours), political science (6 credit hours), humanities (3 credit hours) , and several others.

In addition, each institution could add up to 6 credit hours courses on the top of 42 required credit hours. The faculty of the University of North Texas itself has adopted its own “University Core Curriculum,” (UCC) of forty-seven credit hours, with a well-defined distribution of these hours between humanities, social science and natural science courses [2]. What mitigates these circumstances from the point of view of a curriculum planner is that the State requirements are essentially a subset of the University requirements. Therefore, one may satisfy both requirements/constraints by simply prescribing the required forty-seven credit hours mandated by the University. The State-imposed constraint is satisfied by the courses included in these

credit hours.<sup>1</sup>

Another, and not always apparent constraint in the development of an Engineering curriculum, is the existing structure of courses of the natural sciences and mathematics. Engineering curricula have a solid foundation in natural science and mathematics and our students typically spend the equivalent of a full academic year taking courses in these subjects. However, these courses are general and have not been designed for engineering students or engineering curricula. As a result, engineering students must take several courses in Mathematics with a combined total of fifteen to twenty credit hours before they can master the mathematical skills that are necessary in engineering practice. The University of North Texas is not an exception to this rule and our students must take six courses in Mathematics in order to learn the skills of linear algebra, vector calculus, probability and statistics.<sup>2</sup>

The last constraint is obvious and universal: the Accreditation Board of Engineering and Technology (ABET) has several criteria that must be met by all accredited programs. Since accreditation is essential, indeed vital, to all programs offered by public universities, fulfillment of these criteria must be an integral part of all engineering curricula.

#### **B. Elements of the Mechanical and Energy Engineering curriculum:**

The curriculum of the Mechanical and Energy Engineering Department has been designed to satisfy all the constraints of the previous subsection and four essential elements:

- **Mathematics and basic sciences courses:** These courses offer the students a solid foundation in Mathematics and Natural Science as well as needed mathematical and scientific tools that are necessary or useful in engineering practice.
- **Humanities and social-science courses:** These courses help satisfy the University Core Curriculum as well as the curriculum required by the State of Texas. Whenever possible, courses that are relevant or peripheral to a Mechanical and Energy Engineering curriculum have been designated as “required electives.” Examples of such courses are a course on Environmental Ethics, offered by the Department of Philosophy, which satisfies a requirement in the area of humanities and a course on the environmental impacts on cultures and society, which is offered by the Department of Geography and satisfies one of the requirements in the area of social sciences. The rest of these courses have been designed to give the students a good exposure in liberal arts and artistic creativity.
- **Core mechanical and energy engineering courses:** This is the core of the curriculum of the new program and consists of all the mechanical engineering courses that give students a solid foundation of the discipline of mechanical engineering. A small number of courses on energy engineering are also included in this core curriculum, which offer to the students an excellent and needed specialization, without omitting any of the

---

<sup>1</sup> It must be pointed that, at the writing of this paper, the State of Texas requires that, from 2008-09, the minimum degree requirements of all higher education degree programs must be close to 120 credit hours. This has prompted the faculty of the University of North Texas, as well as other Universities in the State, to start reconsidering the number of credits in the University core curriculum. It is expected that in 2006-07 there will be a significant change in the required core curricula. This will prompt a similar revision of the Mechanical and Energy Engineering curriculum, at least in the number of credit hours required by the University core curriculum.

<sup>2</sup> At the time of the writing of this paper, the faculties of Mathematics and Mechanical and Energy Engineering have been engaged in a dialogue to mitigate this constraint, by combining a number of required courses in Mathematics.

fundamental subjects of a normal mechanical engineering curriculum.

- **Career/technical electives:** These are truly elective courses, chosen by the students. The courses that are offered include a number of courses on energy-related subjects, advanced materials science and technology, mechanics and design practice. A recommended course in this category is a course on Entrepreneurship, offered by the College of Business.

**C. The Mechanical and Energy Engineering curriculum:**

Taking into account the programmatic constraints of the curriculum and the four essential elements of the Mechanical and Energy Engineering, we designed a model program that leads to the Mechanical and Energy Engineering degree. This program was adopted by the faculty of the Mechanical and Energy Engineering Department, the curriculum committee of the faculty of the College of Engineering and the pertinent committee of the faculty of the University. Tables A, B, C, and D show the constituent courses of this program, during every year (two semesters) of study and the number of credit hours associated with each course.

**Table A. Freshman year of study**

Calculus I	4	MATH1710	Calculus II	3	MATH1720
Program Development	4	CSCE1020	Mechanics	3	PHYS1710
Learning to learn	2	EENG1910	Mechanics Lab	1	PHYS1730
MEE practice I	1	MEEN1110	Gen. Chemistry for Science Majors	3	CHEM1410
UCC course (Wellness)	3		Laboratory for Gen. Chemistry	1	CHEM1430
English	3	ENGL1310/13	Technical Writing (UCC)	3	ENGL2700
			MEE practice II	1	MEEN1210
Total credit hours	17			15	

**Table B. Sophomore year of study**

Linear Algebra and Multivariate Calculus	4	MATH2700	Differential Equations	3	MATH3310
Electricity and Magnetism	3	PHYS2220	Thermodynamics	3	MEEN2210
Statics and Dynamics	4	ENGR2303	Computer Aided Engineering	3	MEEN2250
Professional Presentations (UCC)	3	ENGR2060	Mechanics of Materials	4	ENGR2332
Culture Env. & Society (Soc. Sci.)	3	GEOG1170	UCC course (Hist.)	3	
			UCC course (Divers.)	3	
	17			19	

**Table C. Junior year of study**

Thermomechanical Energy Conversion	2	MEEN3110	Thermal Engineering Projects	2	MEEN3125
Fluid Mechanics and Convection	3	MEEN3120	Laboratory and Instrumentation	3	MEEN3240
Conduction and Radiation	2	MEEN3210	Dynamics, Vibrations and Control	3	MEEN3230
Circuit Analysis	3	EENG2610	Engineering Materials	3	MEEN3245
Machine Elements	3	MEEN3130	UCC course (Poli. Sci.)	3	
Contemp. Environmental Issues (UCC)	3	PHIL2500	UCC course (Vis. Arts)	3	
	16			17	

**Table D. Senior year of study**

MEE Design I	3	MEEN4150	MEE Design II	3	MEEN4250
Nuclear Energy	3	MEEN4112	Entrepreneurship*	3	MGMT3850
Alternative Energy Sources	3	MEEN4110	TE Elective	3	MEEN42xx
UCC course (Hist.)	3		TE Elective		MEEN42xx
TE Elective	3	MEEN41xx	UCC course (Poli. Sci.)	3	
	15			15	

\* May be substituted by any other Technical Elective (TE) course.

The designation UCC in the courses denotes a course that must be taken to satisfy the University Core Curriculum, with the recommended subject of the course in the following parenthesis. Students may choose among several elective courses in a particular category or subject, which are listed in the University catalogue [2]. Courses that are planned to be offered by the Mechanical and Energy Engineering Department are designated with the prefix “MEEN.” It must be pointed out that almost the entire freshman program of study may be taken outside the Mechanical and Energy Engineering Department. This was designed in order to allow transfer students to enter the Mechanical and Energy Engineering program. The two single-credit courses during the freshman year, MEE practice I and MEE practice II are not prerequisites to any other course and may be taken by transfer students at any time during their studies. The main reason for the placement of these courses in the freshman year is to familiarize the students with the faculty and program of the Department and, thus, improve the retention of freshmen. There will be set of courses related to environmental engineering and other topics relevant to energy engineering under technical elective courses (TE) as listed above.

### **Innovations in the Mechanical and Energy Engineering Curriculum:**

The principal innovation in this curriculum is its designation. While several Mechanical Engineering programs have a “concentration” in energy studies, this is the first, and currently the only degree program within the discipline of Mechanical Engineering that has the specific degree designation “Mechanical and Energy Engineering.” In the following paragraphs we summarize other innovative aspects of the curriculum:

1. All freshmen are required to take the “Learning to Learn” course, which is designed to provide them with a thorough knowledge of their cognition abilities as well as the skills

to educate themselves inside and outside of the classroom. This course is taught by faculty of the College of Education in the tradition of the student-oriented philosophy of the University.

2. In order to facilitate the experiential learning of students all required courses are planned around significant course projects. These projects are open-ended may be experimental, numerical or in a few cases, analytical. Their inclusion in the curriculum aims at offering to all students experiential comprehension of the subject matter.
3. The fundamentals of thermodynamics, excluding the subject of themomechanical energy conversion (cycles, combustion, etc.) are taught in a single sophomore level course. This enables the students to take all the other thermal science courses during the fall semester of their junior year.
4. During the first semester of the junior year, all the students in the Mechanical and Energy Engineering program must take a course on thermomechanical energy conversion (cycles, combustion and chemical equilibria) and complete their knowledge of applied engineering thermodynamics.
5. The course of fluid mechanics is combined with convection heat transfer, while the other two modes of heat transfer, conduction and radiation, are taught in a separate, shorter course. This combination of the material is a consequence of the importance of fluid flow in the exposition of convection and the common theory of the advection of scalars, such as mass and energy advection. The common exposition of the two subjects also treats similarly and in a unified way concepts such as momentum and thermal boundary layers.
6. A project course on “thermal engineering projects,” offered in the second semester of the junior year, is taught jointly by the professors who taught the thermal science courses and serves as the cornerstone project course for all the thermo-fluid concepts the students have been taught in the previous semester.
7. The senior-year courses are reserved for the typical capstone design course and two required courses on nuclear energy and alternative energy sources. These and technical elective courses, including a recommended course on entrepreneurship, form the bulk of the senior year curriculum.
8. Technical elective courses are planned to be offered with variable credit hours. For example, single credit courses on fuel cells, fusion, geothermal, solar and wind energy are planned, while other courses, such as computational fluid dynamics, advanced fluid dynamics, HVAC, multiphase flow, etc. may be offered as two- or three- credit hour courses. The rationale behind the variable credit technical elective courses is to offer the students a variety of technical topics and a rich knowledge in the energy field. It must also be pointed out that some of these courses will be offered in an “executive” style, during one or two weeks at the beginning or at the end of the Spring semester. The “Maymester” teaching period, which is part of the academic calendar of the University of North Texas provides an ideal setting for such academic offerings.
9. The teaching of professional ethics will be dispersed throughout the four years of the curriculum. For pedagogical reasons, cases of ethics and professionalism will be taught in conjunction with the pertinent units of theory.
10. Applied statistics will be taught during the course of “laboratory and instrumentation,” where their exposition and elucidation is relevant to the mechanical engineering practice.
11. Development of an assessment plan to meet ABET criteria and to show success of the



program is in progress.

**Acknowledgements:**

The planning efforts for the creation of the Mechanical and Energy Engineering Department were supported by a grant from the National Science Foundation, grant number NSF 0530647.

**References:**

1. International Energy Agency, *Key World Energy Statistics*, IEA Press, 2006.
2. University of North Texas, *Undergraduate Catalog, 2006-2007 Bulletin*, UNT division of University Relations, Denton TX, 2006.