The Nuclear Engineering and Mechanical Engineering Concurrent Majors Program at the Pennsylvania State University

L. L. Pauley, R. M. Edwards, L. E. Hochreiter
Department of Mechanical And Nuclear Engineering
The Pennsylvania State University

Summary

A mechanical & nuclear-engineering concurrent majors program has been developed at the Pennsylvania State University with the intent of increasing the interest and enrollment in the nuclear engineering area. The program closely integrates both the mechanical and nuclear engineering required courses into a logical sequence such that it requires only a slightly higher academic load during the semester as well as one additional semester of work. Upon successful completion of the program, the student receives two separate Bachelor of Science degrees, in nuclear and mechanical engineering. The program has gained significant popularity at Penn State with thirty-two students currently enrolled.

Introduction

By the mid 1990's, the undergraduate enrollment in nuclear engineering, across the nation, had significantly decreased such that many Nuclear Engineering Programs and Departments were discontinued or merged into other programs. Some of the mergers resulted in the eventual disappearance of the Nuclear Engineering Program as a viable degree-granting program. While the undergraduate-program enrollment decreased nationwide, the nuclear-engineering graduate programs remained strong and continued to attract students from overseas as well as some students from the United States and the Americas.

A similar undergraduate enrollment situation existed at The Pennsylvania State University (PSU), which has one of the oldest nuclear-engineering undergraduate programs in the United States. Discontinuation of the program was not considered as an option due to the large percentage of nuclear-generated electrical power within Pennsylvania (40%) and the large corporate and federal nuclear organizations within the state, which contribute significantly to the state employment and revenue.

The approach taken at PSU was to merge the Nuclear Engineering Program, as a separate degree granting program, with the Mechanical Engineering Program into a single Mechanical and Nuclear Engineering Department (MNE). Part of the rational for the merger was that there are several commonalties between the two programs and that there was hope that nuclear engineering might be able to attract students from mechanical engineering, which was over-subscribed. The merger has been a success and the enrollment in nuclear engineering has significantly increased over the last five years. The enrollment increases are due to active recruiting of high school students, a more favorable impression of nuclear power as a viable

long range energy source for the nation, and the initiation of an MNE concurrent majors program at PSU, which grants two separate, but integrated, BS degrees in nuclear and mechanical engineering.

Multiple Majors Program

With the merger, the faculty of both the Mechanical and Nuclear Engineering Programs closely examined the individual programs, in detail, for commonality. It was found that there was significant overlap between the two programs and the same detailed material was being taught in both programs but sometimes in separate courses under different titles. Both programs have the first two years nearly in common since the students in either program are required to take the same mathematics, physics, chemistry, and English courses. In addition, the nuclear-engineering students also take the same engineering-mechanics courses such as statics, dynamics, and strength of materials, plus laboratory, as the mechanical-engineering students. Therefore, the significant difference between the two programs only occurs in the final two years where the students specialize in a particular discipline. The commonality of the first two years, including the courses in mechanics, is unique to the PSU engineering programs as compared to engineering programs at other universities.

When examining the junior and senior year courses between the two programs it was also found that the nuclear-engineering and mechanical-engineering students also take the same thermodynamics, fluid mechanics, and heat transfer courses, taught by the mechanical-engineering faculty. The only difference is that mechanical-engineering students take two semesters of thermodynamics whereas the nuclear-engineering students only take one semester. The Nuclear Engineering Program of courses is shown in Figure 1 for the four-year program and the Mechanical Engineering Program of courses is shown in Figure 2. There are 129 credits that are required for graduation in nuclear engineering and 137 credits that are required in mechanical engineering.

As mentioned above, when examining the individual courses in each program, on a lecture-by-lecture basis, it was found that while the course name and number was different between programs, the same material was being covered or there was significant overlap of the material. An example of this is statistics. There is a specific requirement in the Mechanical Engineering Program for a basic statistics course while in the Nuclear Engineering Program, the material on statistics is covered across several nuclear-engineering courses. After reviewing the coverage of statistics across the Nuclear Engineering Program, the mechanical-engineering faculty agreed in a vote that the statistics content in nuclear-engineering courses satisfied the statistics requirement in mechanical engineering.

As a result of the detailed analysis of the course content, a concurrent majors program was developed which took advantage of the large degree of course and content overlap as well as the large number of electives that were allowed in each individual program. A required course from one degree could be used as a technical elective in the other program. This reduced the total number of credits required to complete the two degrees. The multiple majors program is shown in Figure 3 and contains the required courses for both mechanical and nuclear engineering. Comparing Figure 3 to Figure 1 and 2 will indicate that the required courses in each program are preserved in the multiple majors program. It should also be mentioned that a student in the multiple majors program participates in both the mechanical-engineering and nuclear-engineering capstone design courses.

Individual course substitutions were reviewed and approved by the joint nuclear and mechanical-engineering faculty. Through the MNE multiple majors program, a student normally enrolled in nuclear engineering can obtain a second, independent, BS degree in mechanical engineering by taking an additional 28 credits beyond that required for the nuclear-engineering degree. Similarly a student enrolled in mechanical engineering can obtain a second, independent, BS degree in nuclear engineering by taking an additional 20 credits beyond that required for the mechanical-engineering degree.

Planning for the program is important since courses have to be taken in a particular sequence. The nuclear-engineering courses are offered only once a year, where as the mechanical-engineering courses are offered more frequently. Students who wish to participate in the multiple majors program have a detailed course planning session with Dr. Pauley, the Professor-in-Charge of Undergraduate Programs in the Mechanical and Nuclear Engineering Department, as well as Dr. Brenizer, the Program Chair of the Nuclear Engineering Program. With careful planning, the required additional courses for completion of both majors can be accomplished with a slightly higher semester load and one additional semester of work such that the multiple majors program typically requires 4.5 years for completion. Since the average time for an engineering student to graduate at PSU is approximately 4.5 years, independent of the multiple majors program, there can be very little difference between the graduation times of the students in the single and multiple majors programs.

Although there is no formal minimum grade-point average required for entrance into the multiple majors program, each student's previous performance is carefully reviewed before being accepted into the concurrent majors. The student needs to have demonstrated a solid background in mathematics, physics, and engineering mechanics to be accepted into the multiple majors program. He or she is fully informed about the increased workload that is required. The Grade Point Average (GPA) of the students currently enrolled in the multiple majors program is 3.43 and can be compared to that for the Mechanical Engineering Program (3.07) and Nuclear Engineering Program (3.26) alone. This comparison indicates that the students in the concurrent majors program are stronger than the students in the individual program. Clearly, the concurrent majors program is not for the faint-hearted and we encourage only the better students to pursue the program.

For students in the concurrent majors program, industry co-operative assignments are usually discouraged, and summer internships are recommended. Co-operative assignments, while providing valuable industrial experience, usually require an additional year for graduation if the student completes all three co-operative assignments. For students in the concurrent majors program, there are significant opportunities for summer employment. Nuclear utilities, the Nuclear Regulatory Commission, and companies such as Westinghouse, Framatome, Bettis Atomic Power Laboratory, Knolls Atomic Power Laboratory and others have all been hiring nuclear engineering and concurrent major students. In this manner, the students can obtain meaningful industrial work experience in the summers without the need of a longer co-operative assignment.

Penn State hosts Engineering Open House and Spend-a-Summer-Day (four times in the summer) for high school students and their parents to introduce the various engineering programs to the students and parents and to show them our facilities on campus, including the nuclear reactor. The concurrent majors program is also presented and has generated a

significant amount of interest, particularly with the parents. Our interpretation of the interest is that the parents view nuclear engineering with some uneasiness since it is a very specific area. However, when coupled with the mechanical-engineering degree, we believe they feel that their son or daughter will have much more employment flexibility. Therefore, they become supportive of the concurrent majors program.

It should be noted that students at Penn State have been previously allowed to pursue two majors in any two programs of their choice, with permission of the colleges. This has also been true in mechanical and nuclear engineering. In most cases, however, the formulation of a plan to complete the two majors is usually the student's responsibility, with assistance from faculty advisors. In developing the MNE concurrent majors program, the MNE faculty has worked to maximize the overlap in the two degrees and has also approved course substitutions for students in the concurrent majors program. A curriculum plan has also been prepared showing students the semester scheduling of courses to weave the course sequencing of the two programs. This has allowed the MNE department to actively promote the concurrent majors program to students who had not considered this option before. In addition to presenting this option to prospective Penn State students, all students who declare the mechanical-engineering major in the sophomore year are emailed a description of the concurrent majors program in spring semester of their sophomore year. This allows students to consider the program and begin the nuclear engineering sequence of courses in fall semester. Since nuclear-engineering courses are only taught once a year and the four-semester sequence of courses begins in fall, it is important for students to decide to pursue the concurrent majors before beginning the junior year. If not, the concurrent majors will require a minimum of five years instead of four and a half.

Results and Conclusions

The concurrent majors program has been a significant success. In fall 2000, the first year that the MNE concurrent majors was promoted, eight students entered the concurrent majors program with six nuclear-engineering students adding mechanical engineering and two mechanical-engineering students adding nuclear engineering. In the fall of 2002, the enrollment had grown to thirty-two students in the program with eleven nuclear-engineering students adding mechanical engineering and twenty-one mechanical-engineering students having added nuclear engineering. While the enrollment in the nuclear-engineering program has grown, approximately one-half of the total undergraduate students in nuclear engineering are also pursuing a degree in mechanical engineering. The increase in the enrollment is shown in Figure 4. Shown in blue on this figure is the number of junior and seniors pursuing the nuclear-engineering degree alone. The students who were first enrolled in nuclear engineering and then added mechanical engineering as the second major are shown red. The students who were first enrolled in mechanical engineering and then added nuclear engineering as the second major are shown in green. Also included on the figure is the number of nuclear-engineering undergraduates (juniors and seniors) nationally. (In order to show these data on the same figure, the national enrollments were divided by ten.) The rise in the nuclear-engineering enrollments at Penn State corresponds to the merger between nuclear and mechanical engineering (July 1998). The recovery of the nuclear-engineering enrollments at Penn State was two years ahead of the national recovery. Although the national enrollments have increased only slightly since 2000 (8%), the Penn State enrollments have more than doubled. In 1997, Penn State had 5% of the students enrolled in nuclear engineering nationally. In 2002, 10% of nuclear-engineering students were at Penn State. We attribute this in no small

part to the concurrent majors program. In fact, the number of students at Penn State pursing the concurrent majors (32) is almost equal to the rise in the national enrollments in nuclear engineering since 2000 (37). It is difficult to say how many concurrent majors students would have chosen only nuclear engineering if the concurrent majors program were not promoted. But it is observed that the number of students only pursuing a nuclear-engineering degree has not increased significantly since 1998.

The reasons for the popularity are several-fold. There is a specific industry that is associated with nuclear engineering with which the students can identify. This is different than mechanical engineering, which by its very nature is very broad. Also, there is targeted financial support for students in nuclear engineering from the Department of Energy, American Nuclear Society, and the nuclear utilities, which the concurrent majors students can apply and receive. As mentioned earlier, there are ample, challenging, summer internships at nuclear utilities, the Nuclear Regulatory Commission, national laboratories, and companies in the nuclear industry. In addition, there is an acknowledged manpower shortage in these same companies and laboratories, due to the lower student enrollments in nuclear engineering that have existed over the last two decades. The labor force in the nuclear industries is aging and a large fraction of that force is reaching retirement age. Therefore, there are significant opportunities for young engineers in nuclear engineering. In Spring 2002, the first two students pursuing the MNE concurrent majors program graduated and are gainfully employed in the nuclear industry.

The response on the concurrent majors program, from the different segments of the nuclear industry has been very favorable. The companies, laboratories, and government agencies realize that they are getting twice the employee skills for essentially the same cost. They recognize that an employee with multiple degrees has more flexibility and can address a wider range of issues that are important, and that a particular individual requires less initial training. While the nuclear industry hires both mechanical and nuclear engineers, with the concurrent majors, the industry believes it is getting the best of both.

FRESHMAN

1ST Semester		2nd Semester	
MATH 140 - Calculus I	4	MATH 141 - Calculus II	4
CHEM 12 - Chemical Principles	3	†† CHEM 13 - Chemical Principles	3
ED&G 100 – Engineering Design	3	PHYS 211 – Mechanics	4
ENGL 15 or 30 – Composition	3	ECON 2, 4, or 14	3
Arts, Humanities, Social Sciences	3	Arts, Humanities, Social Sciences	3
First-Year Seminar	1	Seminar (optional)	1
	17 cr		17 cr

SOPHOMORE

3rd Semester		4th Semester	
MATH 220 – Matrices	2	MATH 251 – Ord./Part. Diff. Equations	4
MATH 231 – Calculus III	2	PHYS 214 – Wave & Quan. Phys	2
PHYS 212 – Electricity & Magnet	4	EMCH 12 – Dynamics	3
EMCH 11 – Statics	3	EMCH 13 - Strength of Materials	3
SPCOM 100A/B – Effective Spec.	3	ME 30 - Engr. Thermodynamics	3
CMPSC 201 – Fortran or C Prog	3	Health & Physical Activity	1.5
	17 cr		16.5 cr

JUNIOR

5th Semester		6th Semester	
ME 31 – Engr. Thermodyn. II	3	ME 51 - Mechanical Design	3
ME 33 - Fluid Flow	3	ME 54 - Dynamics of Mech. Systems	3
ME 50 - Machine Dynamics	3	ME 82 - Mech. Engr. Measurements	3
EE 305 - Electrical Meas. Syst.	3	IE 312 – Product Design/Mfg. Proc.	3
EMCH 215 – Engr. Materials	2	ENGL 202C - Technical Writing	3
MATSE 259 - Engr Materials	3	Arts, Humanities, Social Sciences	3
	17 cr		18 cr

SENIOR

7th Semester		8th Semester	
ME 440 - Modeling of Dyn. Sys	3	** ME 414W or ME 415W	4
ME 412 – Heat Transfer	3	† Engineering Technical Elective	3
† ME Technical Elective	3	† General Technical Elective	3
† Engineering Technical Elective	3	# ME Lab	1
# ME Lab	1	Arts, Humanities, Social Sciences	3
* Statistics Elective	3	Arts, Humanities, Social Sciences	3
Health & Physical Activity	1.5		17 cr
	17.5 cr		

137 MINIMUM TOTAL CREDITS

Students entering PSU after Spring 1993 must achieve C or better in each underlined course (Policy 82-44)

\# Students must take at least two of the following lab courses: ME 83, ME 84, ME 85, ME 86, ME 87, EMCH 216, or one of these courses if ME 462(4) is taken as a technical elective.

† Students must take no less than one ME Technical Elective(METE), 400 level ME course. Engineering Technical Electives(ETE) can be any 400-level engineering course, General Technical Electives (GTE) can be any math, science, or engineering course beyond the level required for the BSME degree. All courses used as technical electives must not be required elsewhere in the program.

†† Students can take BIOL 141 in place of CHEM 13.

* Students must take one of the following: STAT 401, STAT 414, STAT 418, or IE 424.

** Students may take IE 430 & 1 credit of ME 497, instead of ME 414W or ME 415W

Three rotations of Engr Co-op (ENGR 295, ENGR 395, and ENGR 495) can be used as 3 credits of GTE.

Six ROTC credits may be substituted for 3 credits of ETE and 3 credits of GTE upon completion of ROTC program.

Figure 1. Mechanical Engineering B.S. Program.

FRESHMAN

1st Semester			2nd Semester		
MATH 140	Calculus I	4	MATH 141	Calculus II	4
CHEM 12	Chemical Principles	3	PHYS 211	Mechanics	4
CHEM 14	Experimental Chemistry	1	First-Year Seminar		1
ED & G 100	Engr Design & Graphics	3	ECON 2, 4 or 14(Social Science)		3
ENGL 15 or 30	Rhetoric & Composition	3	Arts, Hum., Soc. Beh. Sciences		3
[1]Arts, Hum., Soc. Beh. Sciences		3	Health & Physical Activity		1.5
		17			16.5

SOPHOMORE

3rd Semester			4th Semester		
MATH 230	Calculus III	4	MATH 251	Ord. & Partial Dif. Eqns.	4
PHYS 212	Electricity & Magnetism	4	PHYS 214	Waves & Quantum Phy	2
E MCH 11	Statics	3	M E 30	Engr. Thermodynamics I	3
CMPSC 201	Programming	3	EMCH 12	Dynamics	3
[1]Arts, Hum., Soc. Beh. Sciences		3	EMCH 13 or 13D	Strength of Materials	3
		17	Health & Physical Activity		1.5
					16.5

JUNIOR

5th Semester			6th Semester		
NucE 301	Fund. of Reactor	4	NucE 302	Intro. To Reactor Des.	4
NucE 309	Analy. Tech. In NucE	3	NucE 450	Radiation Det. & Meas.	3
NucE 310W	Issues in Nuc E	2	M E 412	Heat Transfer	3
M E 33	Fluid Flow	3	E E 305	Intro to Elect Meas Sys	3
SPCOM 100A/B	Effective Speech	3	EMCH 215	Mech. Resp. of Mat.	2
		15	EMCH 216	Matl. Lab	1
					16

SENIOR

7th Semester			8th Semester		
NucE 403	Adv. Reactor Design	3	NucE 431W	Nuc. Reactor Core Des.	4
NucE 430	Design Princ. Of Reactor	3	[2]NucE Elect		3
NucE 451	Exp. In Reactor Physics	3	[3]Tech Elect		3
[2]NucE Elect		3	[1]Arts, Hum., Soc. Beh. Sciences		3
ENGL 202C	Technical Writing	3	[1]Arts, Hum., Soc. Beh. Sciences		3
		15			16

129 MINIMUM TOTAL CREDITS

These courses require a grade of C or better for graduation from Nuclear Engineering (Policy 82-44)

[1] An elective course to satisfy Arts, Humanities and Social Sciences requirements, which must be selected from the University General Education handbook.

[2]Nuc E Electives: Select 6 credits from Nuc E 405, 408, 409, 420, 428, 444(1), 445, 460, 470, or 490.

[3]Technical electives include: Nuclear Engineering courses which are not required; courses outside Nuclear Engineering in other engineering departments; chemistry, physics, mathematics, or computer science (remedial courses excluded).

Figure 2. Nuclear Engineering B.S. Program.

.

FRESHMAN

Fall		Spring	
MATH 140	4	MATH 141	4
CHEM 12	3	PHYS 211	4
ED&G 100	3	CHEM 13	3
ENGL 15	3	CHEM 14	1
Seminar	1	ECON 2/4/14	3
AHS	3	AHS	3
Total	17	Total	18

SOPHOMORE

Fall		Spring	
MATH 230	4	MATH 251	4
PHYS 212	4	PHYS 214	2
EMCH 11	3	EMCH 12	3
SPCOM 100	3	EMCH 13	3
AHS	3	ME 30	3
Health/ESACT	1.5	CmpSc 201F+	3
Total	18.5	Total	18

JUNIOR

Fall		Spring	
MATH 220	2	ENGL 202C	3
ME 33	3	ME 50	3
NucE 301	4	ME 412	3
NucE 309	3	NucE 302	4
NucE 310W	2	EE 305	3
ME 31	3	Health/ESACT	1.5
Total	17	Total	17.5

SENIOR

Fall		Spring	
ME 82	3	ME 51	3
NucE 403	3	ME 54	3
NucE 430	3	NucE 431W	4
EMCH 215	2	NucE 450	3
MatSe 259	3	IE 312	3
AHS	3	EMCH 216	1
Total	17	Total	17

9th Semester

NucE/ME Elective	3
ME 414W/415W	4
ME 440	3
ME Lab	1
NucE 451	3
AHS	3
Total	17

*ME students who have taken MATH 231 should enroll in MATH 232 in Fall Semester Junior year. Together MATH 231 and MATH 232 are equivalent to MATH 230. The course content in MATH 232 is used in the Spring Semester Junior year NucE courses.

+The Nuclear Engineering program recommends CMPSC 201F but will accept CMPSC 201C.

Figure 3. MNE Concurrent Majors Program.

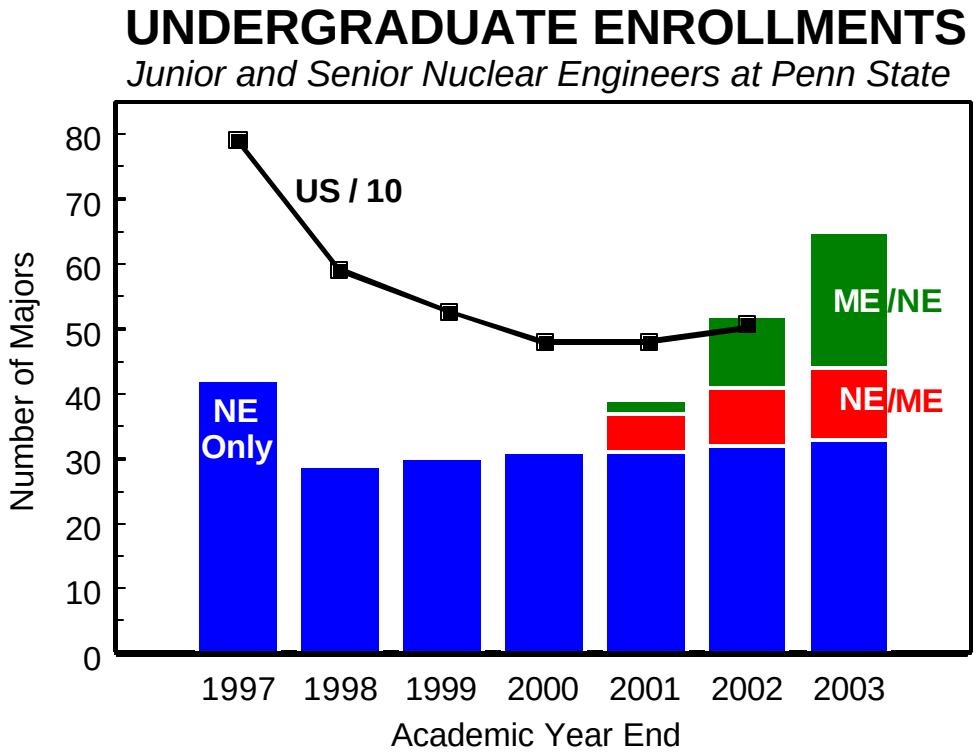

Figure 4. Undergraduate enrollments in nuclear engineering at Penn State. National data is taken from the "Nuclear Engineering Enrollments and Degrees Brief," Oak Ridge Institute for Science and Education, Number 50, April 2002.