Modernization of Nuclear Engineering Undergraduate Curriculum

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Introduction

Nuclear engineering is a well-established field of engineering in the United States, with undergraduate programs stretching back to the 1950's. Among such long-established disciplines, however, nuclear engineering undergraduate programs involve several unusual aspects:

- The number of students per cohort is much smaller than in other programs (e.g., mechanical or electrical engineering).
- The number of faculty is much smaller than in other programs.
- There is no firm consensus in the names and content areas of courses in nuclear engineering.
- There are no undergraduate rankings available from the last two decades, limiting peer and aspirant-peer comparisons among programs.

History of the University of Florida's Undergraduate Nuclear Engineering Curriculum

The University of Florida Nuclear Engineering Program (NEP) has offered an ABET-accredited bachelor's degree in nuclear engineering since 1971. Between 2009 and 2011, the NEP experienced a 100% faculty turnover and was merged into the Department of Materials Science and Engineering, which also offers a degree in Materials Science and Engineering.

When the NEP first reformed in its new configuration, the planned faculty size was six tenured/tenure-track (T/TT) faculty and one non-tenure-track (NTT) faculty. During the 2011-12 Academic Year, the three NEP T/TT faculty members developed an NE-BS curriculum that could meet ABET requirements, train graduates adequately, and be offered by this small faculty with minimal use of adjuncts. Courses offered by other departments were used extensively. This curriculum was made official for Catalog Year 2012. In the following decade, this curriculum has seen few changes in technical coursework. However, since the establishment of this curriculum, the NEP faculty count has increased from three (seven planned) to 12 (13 planned), including 9 T/TT faculty and 3 NTT faculty. This approximately doubles the teaching capacity.

Remaining Relevant to Trends in Nuclear Engineering

A strong nuclear engineering program must remain current with the field. The following areas are of increased relevance since the previous revision to the curriculum.

- Advances in LWR technology, including both large Generation III/III+ reactors such as the AP1000, EPR, and ABWR and Small Modular Reactors such as NuScale.
- Increased reliance on computational skills by industry and use of modern software tools, including Artificial Intelligence and Machine Learning (AI/ML).
- Increased tie between climate change and nuclear engineering, particularly as relates to student motivation to select a nuclear engineering major.
- Increased interest in nuclear forensics, radiochemistry, and plasma/fusion research.

Some of these topics are most appropriately addressed via elective credits. Therefore, the proposed program needs to maintain these options for students.

Goals for the 2022 Curriculum

Prior to the elimination of undergraduate nuclear engineering rankings, the University of Florida was a consistent top ten program at both undergraduate and graduate levels. Recent publications such as US News and World Report have rated the University of Florida among the top public universities in the United States. In 2020, the NEP faculty committed to develop a revised program that could rate among the best, most comprehensive nuclear engineering programs in the United States. 2022 curriculum will:

- Teach and graduate students who could compete for jobs at fission reactor operators and vendors, including large companies and start-up/advanced reactor companies.
- Continue to support the Navy through the Nuclear Propulsion Officer Candidate program.
- Provide a sufficient education in non-reactor applications to future graduate students who could compete for Ph.D. program positions and jobs in these areas.
- Offer students a path to medical physics and other medical applications of radiological sciences, for which graduate study is typically required.
- Expose students to areas of nuclear engineering and related fields (e.g., radiochemistry and plasma/fusion) that they may pursue via graduate studies or jobs in these areas.

Methods: Sources of Information

Leaders in nuclear engineering undergraduate programs are split in primary professional affiliation among the American Society of Engineering Education, the American Nuclear Society's (ANS) Education, Training, and Workforce Development Division, and the Nuclear Engineering Department Heads' Organization. As a result, the NEP faculty soon discovered that no available set of best practices for nuclear undergraduate education was available.

Peer and Aspirant-Peer Comparisons

A significant source of information for curriculum development was a comparison of strong programs. The top twelve graduate programs (which have been the same dozen programs for nearly a decade) were considered. MIT and Oregon State University were excluded for having a different definition of credit hour, leaving ten programs.

The 2012 NEP Curriculum at the University of Florida was found to be out of step with the consensus in the following ways:

- 0/10 required an ethics course.
- 0/10 required a course in probabilistic risk assessment.
- 0/10 allowed biology to count as technical.
- Only 2/10 required a course in statistics.
- 6/10 required a course in economics or the financial aspects of engineering.
- 9/10 have fewer than 5 credits in shielding and radiation protection (0 in 4 programs).
- 10/10 have more computational credits.

In two areas, particularly wide variations among the set of ten programs were found. First, the arrangements of Physics 1 (typically mechanics) and engineering mechanics (statics, dynamics,

and mechanics of materials) were inconsistent. The primary bifurcation of programs was if both statics and Physics 1 were required. Since the University of Florida requires Physics 1 for all engineering degrees, the NEP policy of requiring statics and mechanics of materials, but not dynamics, reflected the consensus of aspirant-peer programs.

Second, the separation of thermal-fluid sciences (thermodynamics, fluid mechanics, heat transfer), reactor thermal hydraulics, reactor systems, and capstone design was inconsistent. There were two independent types of difference in this area. First, some programs (including the 2012 University of Florida NEP) relied heavily on mechanical or chemical engineering thermal-fluids courses; others did this in-house. Second, reactor thermal hydraulics and systems were incorporated into a two-course capstone sequence at several institutions. Finally, the NEP faculty noted the University of Florida had 20 credits in this area, compared to 9/10 aspirant peers between 15 and 18 and one still lower.

Input from ABET Processes

ABET accreditation and associated processes also provided input. Program Criterion 1 for Nuclear Engineering programs was recently modified to require coverage of nuclear fuel cycles. Student Outcome 1 (an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics) was an area in which student performance could be strengthened. This, and its precursor outcome (e), have been on slow, steady decline for multiple six-year ABET cycles. The faculty reviewed student performance on assessments of Outcome 1 and determined that additional mathematics education was advisable, including explicitly nuclear applications taught within the program.

Input from Students, Alumni, and Employers

Direct student feedback was provided in several forms. These include student evaluations of teaching for each course, Town Hall events for students to offer feedback, and informal feedback during classes. This feedback was particularly valuable for identification of courses taught by other departments that were not effective for nuclear engineering students. Input was also sought from the External Advisory Board for the nuclear engineering curriculum. This Board consists primarily of alumni of the program and employers of graduates.

Input from Faculty

Faculty input was involved at all steps of the process, including through submission of ABET student outcome assessments and self-evaluations. In addition to reviewing the information above, many of the nuclear engineering faculty are among leaders in their fields, frequently interfacing with others in their respective technical areas. In Spring of 2021, the NEP faculty voted on 25 questions to enable a new curriculum to be drafted, and a transition process planned.

Results: Changes Made to Produce the 2022 Curriculum

The curriculum change can be considered as a sequence of seven major steps:

1. Elimination of ineffective courses
2. Removal of summer semester
3. Addition of new courses
4. Rearrangement of lower-division coursework
5. Rework of thermal science courses
6. Expansion of nuclear-specific math sequence
7. Repurposing of probabilistic risk assessment course

Tables 1-8 show the technical coursework in the program prior to these steps and for each of the seven steps. Courses re-sequenced at each step are highlighted are highlighted in yellow. New courses at each step are highlighted in green. Courses to be removed in the next step are highlighted in red. Changes to general education (Gen Ed) requirements are governed by higher administrative levels within the university. While the sequencing of these courses was edited to balance student workload across semesters, the details are not part of the present paper.

Step 1: Elimination of Courses

Six courses were eliminated.

- ENU 4934 Fundamentals of Nuclear and Radiological Engineering – this one-credit course does not permit sufficient time to cover an adequate introduction to nuclear physics, reactors, and careers. In a one-credit class, assignments can adversely affect retention, as one skipped or bad homework can change a grade. The lead author has observed students who earned a B or worse often left the program prior to the junior year. This course will be replaced by a two-credit course in Step 3.
- STA 3032 Engineering Statistics – the statistical topics in this course are a poor match for those needed by nuclear engineering students. Further, NEP students do not require significant statistics knowledge until their senior year, by which time retention is quite poor. Students also noted excessive proofs in this course, likely to meet the ABET definition of college math.
- COP 2271 Computer Programming for Engineers – students offered strong negative feedback on this course through all available fora. Faculty also noted that students typically require re-training on programming in later terms. Programming topics will be incorporated into the nuclear-specific math sequence in Step 6.
- EMA 3010 Materials – coverage of biomaterials, polymers, and electronic materials is a significant part of this course, but irrelevant for most nuclear engineering students. Relevant general materials science will be covered in ENU 4800 Introduction to Nuclear Reactor Materials (Spring Junior).
- ENU 4641C Applied Radiation Protection – the NEP had more credits in shielding and radiation protection than aspirant peers. This change eliminates this issue.
- BSC 2010 Integrated Principles of Biology I – students have been urged to take Chemistry 2 instead of biology for many years as the analogy between atomic and nuclear physics is helpful in later courses and no other NE program permits the substitution.

The final two courses eliminated were largely a legacy of the pre-2011 nuclear department at the University of Florida, which also included significant activity in medical and health physics.

Table 1: NEP Curriculum Before 2022 Changes

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2312	Analytic Geometry and Calculus 2	4
PHY 2048/2048L	Physics with Calculus 1 (& Lab)	4
Fall Sophomore		
ENU 4934	Fundamentals of Nuclear and Radiological Engineering	1
MAC 2313	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
STA 3032	Engineering Statistics	3
Spring Sophomore		
	General Chemistry 2 or Chemistry for Engineers 2 or Biology 1	3
COP 2271	Computer Programming for Engineers	2
EGM 2511	Engineering Mechanics: Statics	3
EML 3100	Thermodynamics	3
MAP 2302	Elementary Differential Equations	3
Summer		
EGM 3520	Mechanics of Materials	3
EMA 3010	Materials	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
EGN 3353C	Fluid Mechanics	3
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4001	Nuclear Engineering Analysis 1	4
ENU 4605	Radiation Interactions and Sources 1	4
Spring Junior		
EML 4140	Heat Transfer	3
ENU 4103	Reactor Analysis and Computation 1: Statics	4
ENU 4144	Nuclear Power Plant Reactor Systems 1	3
ENU 4180	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Hydraulics	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
	Technical Elective	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
ENU 4641C	Applied Radiation Protection	2
	Technical Elective	3

Table 2: NEP Curriculum After Step 1 (Elimination of Courses)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2312	Analytic Geometry and Calculus 2	4
PHY 2048/2048L	Physics with Calculus 1 (& Lab)	4
Fall Sophomore		
MAC 2313	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
Spring Sophomore		
MAP 2302	General Chemistry 2 or Chemistry for Engineers 2	3
EGM 2511	Engineering Mechanics: Statics	3
EML 3100	Thermodynamics	3
MAP 2302	Elementary Differential Equations	3
Summer		
EGM 3520	Mechanics of Materials	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
EGN 3353C	Fluid Mechanics	3
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4001	Nuclear Engineering Analysis 1	4
ENU 4605	Radiation Interactions and Sources 1	4
Spring Junior		
EML 4140	Heat Transfer	3
ENU 4103	Reactor Analysis and Computation 1: Statics	4
ENU 4144	Nuclear Power Plant Reactor Systems 1	3
ENU 4180	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Hydraulics	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
	Technical Elective	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
	Technical Elective	3

Table 3: NEP Curriculum After Step 2 (Removal of Summer Semester)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2312	Analytic Geometry and Calculus 2	4
PHY 2048/2048L	Physics with Calculus 1 (& Lab)	4
Fall Sophomore		
MAC 2313	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
Spring Sophomore		
MAP 2302	General Chemistry 2 or Chemistry for Engineers 2	3
EGM 2511	Engineering Mechanics: Statics	3
EML 3100	Thermodynamics	3
MAP 2302	Elementary Differential Equations	3
EGM 3520	Mechanics of Materials	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
EGN 3353C	Fluid Mechanics	3
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4001	Nuclear Engineering Analysis 1	4
ENU 4605	Radiation Interactions and Sources 1	4
Spring Junior		
EML 4140	Heat Transfer	3
ENU 4103	Reactor Analysis and Computation 1: Statics	4
ENU 4144	Nuclear Power Plant Reactor Systems 1	3
ENU 4180	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Hydraulics	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
	Technical Elective	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
	Technical Elective	3

Table 4: NEP Curriculum After Step 3 (Addition of New Courses)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2312	Analytic Geometry and Calculus 2	4
PHY 2048/2048L	Physics with Calculus 1 (& Lab)	4
Fall Sophomore		
ENU 2002	Fundamentals of Nuclear Engineering	2
MAC 2313	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
Spring Sophomore		
MAP 2302	General Chemistry 2 or Chemistry for Engineers 2	3
EGM 2511	Engineering Mechanics: Statics	3
EML 3100	Thermodynamics	3
MAP 2302	Elementary Differential Equations	3
EGM 3520	Mechanics of Materials	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
EGN 3353C	Fluid Mechanics	3
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4001	Nuclear Engineering Analysis 1	4
ENU 4605	Radiation Interactions and Sources 1	4
Spring Junior		
EML 4140	Heat Transfer	3
ENU 4103	Reactor Analysis and Computation 1	4
ENU 4144	Nuclear Power Plant Reactor Systems 1	3
ENU 4180	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Hydraulics	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
ENU 4104	Reactor Analysis and Computation 2	3
	Technical Elective	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
ENU 4180	Introduction to Nuclear Fuel Cycles	3
	Technical Elective	3

Table 5: NEP Curriculum After Step 4 (Rearrangement of Lower-Division Courses)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2313	Analytic Geometry and Calculus 2	4
PHY 2049/2049L	Physics with Calculus 1 (& Lab)	4
CHM 20x6	General Chemistry 2 or Chemistry for Engineers 2	3
Fall Sophomore		
ENU 2002	Fundamentals of Nuclear Engineering	2
MAC 2312	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
EGM 2511	Engineering Mechanics: Statics	3
Spring Sophomore		
EML 3100	Thermodynamics	3
MAP 2302	Elementary Differential Equations	3
EGM 3520	Mechanics of Materials	3
	Technical Elective	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
EGN 3353C	Fluid Mechanics	3
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4001	Nuclear Engineering Analysis 1	4
ENU 4605	Radiation Interactions and Sources 1	4
Spring Junior		
EML 4140	Heat Transfer	3
ENU 4103	Reactor Analysis and Computation 1	4
ENU 4144	Nuclear Power Plant Reactor Systems 1	3
ENU 4180	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Hydraulics	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
ENU 4104	Reactor Analysis and Computation 2	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
ENU 4180	Introduction to Nuclear Fuel Cycles	3
	Technical Elective	3

Table 6: NEP Curriculum After Step 5 (Rework of Thermal Science Courses)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2313	Analytic Geometry and Calculus 2	4
PHY 2049/2049L	Physics with Calculus 1 (& Lab)	4
CHM 20x6	General Chemistry 2 or Chemistry for Engineers 2	3
Fall Sophomore		
ENU 2002	Fundamentals of Nuclear Engineering	2
MAC 2312	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
EGM 2511	Engineering Mechanics: Statics	3
Spring Sophomore		
MAP 2302	Elementary Differential Equations	3
EGM 3520	Mechanics of Materials	3
	Technical Elective	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
ENU 3132	Reactor Thermal Engineering 1	4
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4001	Nuclear Engineering Analysis 1	4
ENU 4605	Radiation Interactions and Sources 1	4
Spring Junior		
ENU 4133	Reactor Thermal Engineering 2	4
ENU 4103	Reactor Analysis and Computation 1	4
ENU 4800	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Engineering 3	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
ENU 4104	Reactor Analysis and Computation 2	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
ENU 4180	Introduction to Nuclear Fuel Cycles	3
	Technical Elective	3

Table 7: NEP Curriculum After Step 6 (Expansion of Nuclear Math Sequence)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2313	Analytic Geometry and Calculus 2	4
PHY 2049/2049L	Physics with Calculus 1 (& Lab)	4
CHM 20x6	General Chemistry 2 or Chemistry for Engineers 2 or	3
Fall Sophomore		
ENU 2002	Fundamentals of Nuclear Engineering	2
MAC 2312	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
EGM 2511	Engineering Mechanics: Statics	3
Spring Sophomore		
MAP 2302	Elementary Differential Equations	3
EGM 3520	Mechanics of Materials	3
ENU 4001	Nuclear Engineering Analysis 1	4
	Technical Elective	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
ENU 3132	Reactor Thermal Engineering 1	4
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4605	Radiation Interactions and Sources 1	4
ENU 4003	Nuclear Engineering Analysis 2	4
Spring Junior		
ENU 4133	Reactor Thermal Engineering 2	4
ENU 4103	Reactor Analysis and Computation 1	4
ENU 4800	Introduction to Nuclear Reactor Materials	3
	Technical Elective	3
Fall Senior		
ENU 4134	Reactor Thermal Engineering 3	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
ENU 4104	Reactor Analysis and Computation 2	3
Spring Senior		
ENU 4145	Risk Assessment for Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
ENU 4180	Introduction to Nuclear Fuel Cycles	3
	Technical Elective	3

Table 8: NEP Curriculum After Step 7 – Final (Repurposing of PRA Course)

Fall Freshman		Credits
CHM 20x5/2045L	General Chemistry 1 or Chemistry for Engineers 1 (& Lab)	4
ENU 1000	Introduction to Nuclear Engineering	1
MAC 2311	Analytic Geometry and Calculus 1	4
Spring Freshman		
ENC 3246	Professional Communication for Engineers	3
MAC 2313	Analytic Geometry and Calculus 2	4
PHY 2049/2049L	Physics with Calculus 1 (& Lab)	4
CHM 20x6	General Chemistry 2 or Chemistry for Engineers 2 or	3
Fall Sophomore		
ENU 2002	Fundamentals of Nuclear Engineering	2
MAC 2312	Analytic Geometry and Calculus 3	4
PHY 2049/2049L	Physics with Calculus 2 (& Lab)	4
EGM 2511	Engineering Mechanics: Statics	3
Spring Sophomore		
MAP 2302	Elementary Differential Equations	3
EGM 3520	Mechanics of Materials	3
ENU 4001	Nuclear Engineering Analysis 1	4
	Technical Elective	3
Fall Junior		
EEL 3003	Elements of Electrical Engineering	3
ENU 3132	Reactor Thermal Engineering 1	4
EGS 4034	Engineering Ethics and Professionalism	1
ENU 4605	Radiation Interactions and Sources 1	4
ENU 4003	Nuclear Engineering Analysis 2	4
Spring Junior		
ENU 4133	Reactor Thermal Engineering 2	4
ENU 4103	Reactor Analysis and Computation 1	4
ENU 4800	Introduction to Nuclear Reactor Materials	3
	Technical Electives	6
Fall Senior		
ENU 4134	Reactor Thermal Engineering 3	4
ENU 4191	Elements of Nuclear and Radiological Engineering Design	1
ENU 4612/4612L	Nuclear Radiation Detection and Instrumentation (& Lab)	4
ENU 4630	Fundamental Aspects of Radiation Shielding	3
ENU 4104	Reactor Analysis and Computation 2	3
Spring Senior		
ENU 4145	Risk Assessment and Economic Analysis of Radiation Systems	3
ENU 4192	Nuclear and Radiological Engineering Design	3
ENU 4505L	Nuclear and Radiological Engineering Laboratory 1	3
ENU 4180	Introduction to Nuclear Fuel Cycles	3
	Technical Elective	3

Step 2: Removal of Summer Semester

Per administrative orders, the program was re-sequenced to eliminate a listed summer semester.

Step 3: Addition of New Courses

Three new courses are added to the 2022 curriculum.

- ENU 2002 Fundamentals of Nuclear Engineering – Spring Sophomore – this-two credit course replaces the one-credit ENU 4934, allowing for more depth and rigor. Student success in junior-year courses requires an introduction to basic nuclear physics, which is not offered as part of the required physics sequence, and nuclear reactors. Further, students need to be made aware of the areas of nuclear engineering, possible careers, and paths through their undergraduate studies (UG research, internships, co-ops, other opportunities) early in the curriculum to plan their path to a career or graduate school.
- ENU 4104 Reactor Analysis and Computation 2 – Fall Senior – this course allows for three additional credits of reactor physics (after ENU 4103 Reactor Analysis and Computation 1). This area was deemphasized in 2012 due to the low faculty count and University of Florida focus on nuclear materials rather than reactor physics. The larger faculty size allows for a more robust coverage of this area, on par with peer programs.
- ENU 4180 Introduction to the Nuclear Fuel Cycle – Spring Senior – following the reactor physics sequence, a wider-scope fuel cycles course broadens student perspective and career options and clearly establishes compliance with ABET Program Criterion 1. This course has already been offered at as a popular, well-received, and successful elective.

Step 4: Rearrangement of Lower-Division Coursework

At the end of all these steps, there will be a technical elective in Spring of the Sophomore year. To open some options for this course (particularly radiochemistry and plasma/fusion), the NEP faculty decided to rearrange the lower division such that students will complete their physics and chemistry sequences in time. To achieve this:

- CHM 20x6 Chemistry 2 is moved from Spring Sophomore to Spring Freshman
- EGM 2511 Statics is moved from Spring Sophomore to Fall Sophomore
- A technical elective is moved from Fall Senior to Spring Sophomore

Step 5: Rework of Thermal Science Courses

The 2012 curriculum covers reactor systems and reactor thermal hydraulics within the program. ENU 4144 Nuclear Power Plant Reactor Systems 1 (3 credits) is a largely qualitative course, focusing on factual lectures and notes on current LWR technology. There are few calculations for students to perform, resulting in a course that is lecture heavy and workload light. Conversely, ENU 4134 Reactor Thermal Hydraulics (4 credits) focused on two-phase flow and heat transfer, which includes complex calculations leading to a course that is lecture light and workload heavy. The 2012 program also relies heavily on thermal courses taught by the Department of Mechanical and Aerospace Engineering – Thermodynamics, Fluid Mechanics, and Heat Transfer (each three credits). These courses are designed for students in that

department and cover topics irrelevant to nuclear engineering. These courses total 16 credits, which the NEP faculty found excessive.

In the new curriculum, these courses are integrated into a 3-course, 12-credit sequence:

- ENU 3132 Reactor Thermal Engineering 1 covers thermodynamics, conduction and radiation heat transfer, and the interaction of government and nuclear power (including Nuclear Regulatory Commission [NRC] regulations)
- ENU 4133 Reactor Thermal Engineering 2 covers fluid mechanics, convection heat transfer, and PWR technology.
- ENU 4134 Reactor Thermal Engineering 3 covers two-phase flow, boiling heat transfer, BWR technology, and reactor accident sequences.

Each has a similar workload and mix between quantitative and qualitative content. The qualitative content, associated with lower out-of-class workload, is back-loaded in each semester, balancing other courses for which student workload ramps up in the last few weeks of a term.

Step 6: Expansion of Nuclear-specific Math Sequence

ENU 4001 Nuclear Engineering Analysis 1 is moved from Fall Junior to Spring Sophomore, with ENU 4003 Nuclear Engineering Analysis 2 added to Fall Junior. This sequence also covers introductory programming topics, including input/output to/from text files and more detailed coverage of matrices than offered in COP 2271 Computer Programming for Engineers.

ENU 4001 Nuclear Engineering Analysis 1 retains its previous coverage of linear algebra and greatly expands its coverage of probability and statistics, with an eye towards statistics relevant to radiation detection and probabilistic risk assessment not present in a general engineering statistics course. The probabilistic treatment of radiation interaction fundamentals is also emphasized to provide a basis for Monte Carlo-based modelling. It also covers introductory programming topics, including input/output to/from text files and more detailed coverage of matrices than was previously offered in COP 2271 Computer Programming for Engineers.

ENU 4003 Nuclear Engineering Analysis 2 takes over topics in intermediate ordinary differential equations along with an introduction to partial differential equations focusing on nuclear applications. The course follows up on the programming thread as well, with an introduction to numerical methods. The University of Florida recently required that all programs involve Artificial Intelligence or Machine Learning in at least one course; ENU 4003 Nuclear Engineering Analysis 2 checks this box as part of an introduction to data science that wraps up the course.

Step 7: Repurposing of Probabilistic Risk Assessment Course

Peer comparison showed the NEP was the only program to require a 3-credit course in probabilistic risk assessment for the bachelor's degree. The NEP faculty were split roughly evenly whether the PRA course should continue and, separately, whether a course in engineering economy should be required. Several other institutions integrate PRA and economics into a single course. To better align with common practices in the field, ENU 4145 will be split 60/40

between PRA and engineering economy beginning in Spring 2025. The credit count is reduced by three from 2012. An additional technical elective (three credits) was added to Junior Spring.

Results and Discussion: Effects of the 2022 Curriculum

The first students are more than halfway through the program, allowing observations to be made.

Improved Retention and Increased Cohort Sizes

A major goal of the change in the sophomore Fall course was improved retention in the program. The new course was first taught in Fall 2023. Excluding a dual-enrollment (high school) student taking the course, 75% (15/20) students have advanced to junior-level nuclear courses, as of Fall 2024. This represents a positive trend compared to 71% (17/24), and 65% (13/20) in the two previous years. Informal student feedback is that the expanded sophomore course provided a clearer understanding of what nuclear engineering entails and what to expect in subsequent major courses, which may have contributed to higher retention rates and increased cohort sizes.

The current cohort of juniors has 23 students, as judged based on Spring courses. This is the largest cohort in the University of Florida NEP since the class of 2017. The current cohort of sophomores is still larger (30 students), although some sophomore-to-junior attrition is likely.

Alumni Feedback

The chair of the NEP Advisory Board graduated from the NEP in 2014. When asked to rate and evaluate the changes, he noted that, “The thermal sequence looks like the most standout positive change,” and that, “Inclusion of engineering economy as standard content is [of] high importance”. A 2017 graduate who recently returned to the University of Florida to pursue graduate studies following service in the Navy agreed, stating “I wish I had the opportunity to take those classes”.

Improved Student Performance and Satisfaction

Students in the new math sequence exceeded expectations on the new programming content, despite most students claiming no prior programming experience. High programmatic relevance implied by including it in a nuclear course may enhance student motivation and performance. There was no notable negative impact for the components that moved to earlier coverage in the curriculum plan. The probability and statistics areas were the most challenging components, though the benefit of covering it in a dedicated nuclear class was noted.

The topics of government relation with nuclear power and NRC regulations were moved into the first of the new reactor thermal engineering courses. To measure student performance, approximately 60% of that course’s final exam was reused from the Spring 2023 exam in the predecessor course. Student average performance improved from 73% to 84% on those parts of the exam. The student evaluations of teaching for the relevant courses also increased by

approximately 1.5 points on a 5-point scale between the final old curriculum and first new curriculum cohorts, with comments about the improved quantitative/qualitive mix offered.

Students in the 2024 run of the (Fall Junior) Radiation Interactions and Sources course exhibited strong recollection of material introduced in the Fundamentals of Nuclear Engineering course (taken in Fall 2023). This allowed a more efficient review of interaction basics in ENU 4605, allowing more time to be spent on advanced topics, enhancing student understanding and application of these concepts. The thread of radiation interactions continues in the Fall Senior shielding course; further progress towards advanced topics might be possible there in 2025.

Summary and Path Forward

The University of Florida implemented a major curriculum change beginning with 2022 first year admits, who will graduate in Spring 2026 and are currently juniors in the program. Student performance, satisfaction, and headcount/retention have all improved in the new program. The new curriculum can be characterized as a tentative success.

Changes to ABET requirements are also monitored each year. No ABET changes since 2022 have advised changes in our program. Excluding General Education changes mandated by higher administrative levels, the NEP faculty have maintained this program for 2023, 2024, and 2025 first year admits.

Student and faculty feedback is informally sought on an ongoing basis. One challenge of the new program relates to Spring Sophomore electives. The instructors of two in-program courses, plasma/fusion and radiochemistry, indicated that sophomores are not yet prepared to tackle these topics. As a result, both courses are now kept behind pre-requisites in the Fall of the Junior Year. In Summer 2025, the program will offer a new special topics course, Societal Aspects of Nuclear Technology, without such prerequisites. This course will examine the interactions between society and nuclear technology, covering the field's historical development, regulatory frameworks, energy and medical applications, societal impacts of nuclear accidents, and future innovations.

Future work on the revised curriculum will consider other appropriate nuclear technical electives, as well as opportunities outside the NEP. A more significant reorganization of electives could be achieved if the laboratory courses ENU 4612L and ENU 4505L were taught an extra time. The program will consider these options and review the initial offering of Societal Aspects of Nuclear Technology prior to the 2026 catalog deadline.

The faculty will monitor student progress through graduation, and transition to graduate school and the workforce over the next several years. In or around 2028, the NEP faculty will again perform peer comparisons and formally discuss the revised curriculum at a meeting of the advisory board. At this time, the NEP faculty will determine if another significant curriculum change in required. This target date synchronizes well with our ABET cycle and ensures two cohorts of students will have finished the current curriculum before major changes are discussed.