The Minimum Core for Chemical Engineering: How Much Bathwater Can We Throw Out?

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Abstract

The field of chemical engineering is expanding. Chemical engineers are currently working in such fields as biological processing, biochemical engineering, materials science, environmental engineering, electronic materials, nanotechnology, food processing, and many others, as well as in the more traditional fields of chemical and petrochemical manufacturing and fuels processing. University chemical engineering departments are under pressure – from students as well as from employers – to provide curricula which allow new, young chemical engineers to work effectively in these fields. In addition, there is pressure – particularly from employers – to broaden students' skills and knowledge in "soft" areas – communications, economics, business and management practices, foreign languages, etc. At the same time, there is pressure – particularly from state governments – to avoid "credit-hour creep" and to graduate students in four years. One way to meet these demands is through a layered curriculum in which all chemical engineering students would learn the minimum basic material needed to qualify as chemical engineers and then would add layers of specialization and breadth. It is our contention that a core of about twelve semester hours of chemical engineering courses, together with appropriate chemistry, physics and mathematics, can provide the minimum basic material. There could then be ample room for students to complete their undergraduate education, including laboratory and design work, in a chemical engineering specialty area program which would incorporate applications of the basic core material and fundamental material for the specialty. This paper offers one version of a minimum core along with illustrations of how specialty areas would build on it.

Introduction

The field of chemical engineering is expanding. Chemical engineers are currently working in such fields as biological processing, biochemical engineering, materials science, environmental engineering, electronic materials, nanotechnology, food processing, and many others as well as in the more traditional fields of chemical and petrochemical manufacturing and fuels processing. And it is not just our students who are finding work in these technical areas, but our faculty also. Just look at the contents of *AIChE Journal*[1] or the academic job announcements in *Chemical Engineering Progress*[2]. University chemical engineering departments are under pressure – from students as well as from employers – to provide curricula which allow new, young chemical engineers to work effectively in these fields.

In addition, there is pressure – particularly from employers – to broaden students' skills knowledge in "soft" areas – communications, economics, business and management practices, foreign languages, etc. At the same time, there is pressure – particularly from state governments

– to avoid "credit-hour creep" and to graduate students in four years. The basic problem is that we – faculty, administrators, legislators, employers and the students themselves – want the curriculum to cover too much in too little time.

There are several possible ways to attempt to solve this problem:

- *Benign neglect:* We could, of course, ignore the problem and just keep on doing what we've been doing. The likely result: even greater disconnect between the curriculum and practice.

- *More credit hours:* We could lengthen the degree program. There has been considerable discussion about various forms of five-year, or longer, programs as the first professional degree in engineering. (What this really means, of course, is 25 percent more courses, not necessarily five actual years. For many students, especially in urban schools with large part-time student populations, the program is already more, sometimes much more, than five years long.) A few schools, such as Cornell, tried this approach fifty years ago; but the experiment failed when few other schools joined in and industry appeared satisfied with four-year graduates. Given the strong pressures from legislators, students, and parents not to increase credit hours and program length, it seems unlikely that there will be many five-year bachelors programs or masters-as-the-first-professional-degree programs in the near future.

- *Lesser intensity:* We could cover all the current topics plus additional ones by increasing the breadth of the curriculum and simultaneously decreasing the depth. Reduce most of the typical three-credit courses to two credits by leaving out the more complex material; or cover all the material, but lower our expectations of student comprehension. Then add more elective courses in specialty areas. We would certainly be open to criticism for "dumbing down" the curriculum.

- *More intensity:* We could pack more material into the existing curriculum by reducing the credit hours in some courses, while requiring the students to master all the same material as before. This would allow room for additional courses. In one sense, it could be seen as a bargain for the students and the money-watchers: get three credits worth of material but pay for only two. But chemical engineering courses already have the reputation of being some of the most time-intensive on any campus.

- *Degree proliferation:* We could divide existing degree programs into a number of more specialized ones, reserving the *Chemical Engineering* title for programs concentrating on traditional topic areas. Students instead would earn degrees in *Bioprocess Engineering, Biomedical Engineering, Biochemical Engineering, Environmental Engineering, Energy Systems Engineering,* etc. Many such individual degree programs already exist, and more seem to be appearing each year. The likely result: gradual elimination of the degree in *Chemical Engineering.* We should look to our Chemistry Departments to see how to avoid this. Students there may specialize in organic chemistry, analytical chemistry, physical chemistry, etc., but the undergraduate degree accredited by the American Chemical Society is *Chemistry.*

- *Concentrated core and layered specialization:* One way to address this problem is through a layered curriculum in which all chemical engineering students would learn the minimum basic material common to all fields of chemical engineering and then add layers of specialization and breadth. It is our contention that a minimum core of about twelve semester hours of chemical engineering courses, together with appropriate chemistry, physics and mathematics, can provide the essential minimum basic material. There would then be ample room for students to complete their undergraduate chemical engineering education in a specialty area. Courses in the specialty area would include fundamental material for the specialty and applications of the basic chemical engineering core material in that specialty, along with related laboratory and design work.

The ideas presented in this paper are based, in part, on faculty discussions in the Chemical and Nuclear Engineering Department at the University of New Mexico, where curriculum revision is an ongoing process. To what extent, if any, the department adopts this somewhat radical approach remains to be seen.

Identifying characteristics of a chemical engineer

Two organizations, the Accreditation Board for Engineering and Technology (ABET) and the National Council of Examiners for Engineering and Surveying (NCEES), have defined subject matter areas for undergraduate chemical engineering programs, though with quite different purposes in mind.

ABET's requirements include the well-known "A through K" outcomes criteria for all engineering programs and the requirement for an assessment program with documented results[3]. In addition, ABET requires a minimum of one year of college level mathematics and basic sciences, appropriate to the discipline; a minimum of one and one-half years of engineering topics; and a general education component, with no minimum specified.

The ABET program-specific criteria for chemical engineering specify what they consider the minimum components of an undergraduate chemical engineering program. In addition to a thorough grounding in chemistry and a working knowledge of advanced chemistry, ABET includes the following engineering-related curriculum components for chemical engineering, all of which must be covered for a program to achieve accreditation:

> "…working knowledge, including safety and environmental aspects, of material and energy balances applied to chemical processes; thermodynamics of physical and chemical equilibria; heat, mass, and momentum transfer; chemical reaction engineering; continuous and stage-wise separation operations; process dynamics and control; process design; and appropriate modern experimental and computing techniques."[3]

ABET does not require that these subjects be addressed in specifically-named courses, nor does it further define the subjects. Most undergraduate chemical engineering programs today meet these criteria with specific courses for each, based on a relatively small choice of standard textbooks. All chemical engineering students should learn the well-accepted, scientific principles underlying these topics; but there is no necessity for all chemical engineering students to learn to apply these principles in the same specialty area or in all possible specialty areas.

The Fundamentals of Engineering (FE) examination administered by NCEES is used as the first step in becoming a registered professional engineer and is also used as an outcomes assessment tool by some schools. It consists of a general engineering test in the morning and discipline-specific tests in the afternoon, all tests being multiple-choice in format. A score of approximately 70% is needed to pass the exam; so students need not be proficient in all areas. Engineering-related topics include the following:[4]

- General exam (morning portion)
    - Dynamics
    - Electrical circuits
    - Engineering economics
    - Fluid mechanics
    - Mechanics of materials
    - Statics
    - Thermodynamics
- Chemical engineering exam (afternoon portion)
    - Chemical reaction engineering
    - Chemical thermodynamics
    - Computer and numerical methods
    - Heat transfer
    - Mass transfer
    - Material/energy balances
    - Pollution prevention
    - Process control
    - Process design and economics evaluation
    - Process equipment design
    - Process safety
    - Transport phenomena

The morning exam is weighted heavily toward mechanics and also includes general topics in mathematics, chemistry and physics. The afternoon chemical engineering exam is weighted toward traditional chemical plant processes. Are all of these morning and afternoon topics covered in most chemical engineering undergraduate programs? No. Do most chemical engineers even take the exam? No; some schools require the exam for graduation, but chemical engineers most often obtain jobs that do not require professional registration. Do most chemical engineering seniors and recent graduates who take the FE exam pass? Yes. (Note that NCEES is currently updating the topic areas and the number of questions in each, but there are not likely to be any major changes.)

Keeping in mind the subjects specified by ABET and NCEES, and recognizing the areas of overlap with other engineering and science disciplines, we conclude that there are five key areas which characterize chemical engineers:

- *Knowledge of chemistry:* The issue of what chemistry is essential for chemical engineers is beyond the scope of this paper.

- *Knowledge of material and energy balances and both single- and multi-component thermodynamics:* These are closely-related topics, but they are often taught in separate courses. The result is a lot of repetition.

- *Knowledge of momentum, heat and mass transfer and separation processes:* Momentum and heat transfer are common to some other engineering disciplines; mass transfer and separations are unique to chemical engineering.

- *Knowledge of reaction kinetics and engineering*: The engineering aspects of chemical reactions and reactor design are unique to the field of chemical engineering, not being covered to any significant extent in chemistry or in other engineering fields.

- *Knowledge of and ability to understand and use the concept of an overall integrated process:* Though some other engineering fields, most notably industrial engineering, incorporate the ideas of integrated processes, these concepts are basic to all areas of chemical engineering.

A minimum chemical engineering core with layered specialization

A minimum chemical engineering core could consist of about six integrated hours of material balances, energy balances and thermodynamics; four hours of transport phenomena and two hours of kinetics. Material in these courses is fundamental to all areas of chemical engineering. The courses would concentrate on basic principles and theory, not on applications.

The remainder of the chemical engineering courses would cover theory and fundamentals and applications appropriate for specialty areas. These courses would include aspects of material balances, energy balances and thermodynamics specific to the field; the analysis and design of unit operations specific to the field; and aspects of reaction engineering and kinetics specific to the field. In addition, courses in design, economics and applied mathematics would be based on applications in specific areas, as would the laboratory components of the curriculum.

The portion of the curriculum reserved for specialty areas could be organized in many different ways. There are some topics that can best be taught in traditional lecture/problem style courses. There are other topics that can be taught better through problem-based learning involving students from multiple class levels. There are some topics that are pertinent to several specialty areas; so, obviously, they can be taught in common courses.

This approach to repackaging the curriculum and providing significant specialization in areas other than traditional process plant engineering will better prepare students for the wide variety of subfields of chemical engineering to which they are headed. Rather than having all students try to learn a little bit about a wide range of applications, this approach would permit them to concentrate in areas of greatest interest. It should permit greater depth of knowledge and also free up curriculum space for additional electives and/or non-engineering courses.

With carefully structured specialty area courses, the core-plus-specialty approach should have no trouble meeting ABET criteria for chemical engineering. It should also permit more time to be spent on some of the notorious non-technical "A to K" criteria. Students in programs such as this, however, may be less well prepared to pass the NCEES FE exam. A current traditional BSChE curriculum, however, also can lack some of the topics covered in the FE exam. Nevertheless, the pass rate for those chemical engineering students who take the exam is quite high. (This may be due in part to the facts that only a small percentage of senior chemical engineers take the exam. Those who do so at schools where it is not required tend to be among the more accomplished students, and the passing score is only about 70 percent.)

There are, of course, additional skills essential for all entry-level engineers, and for entry-level positions in many other fields as well. Any chemical engineering curriculum should provide means to assure that students attain these skills, whether through courses or individual competency testing. Broadly speaking, these skills are the ability to build on previous knowledge and the ability to communicate complex ideas. More specifically, in today's world, they include:

- The ability to find and analyze both print and web-based information sources.
- The ability to use computer spread-sheet and mathematics packages, such as *EXCEL* and *MATHCAD*.
- The ability to use computer-based computation tools specific to the discipline.
- The ability to communicate effectively in both written and spoken English.
- The ability to use common communication tools, such as *WORD* and *POWERPOINT*.

Possible impact on a typical current curriculum

Consider how the minimum core approach would impact a typical BSChE curriculum – for example, the one at the University of New Mexico. It currently consists of 132 semester hours, distributed as follows:

Required math and science courses	48 hours
Non-technical university core and electives	27 hours
Required chemical engineering courses	45 hours
Chemical engineering electives	6 hours
Other engineering courses	6 hours

The required chemical engineering courses include the following areas.

First year introduction	1 hour
Material and energy balances	4 hours
Thermodynamics	6 hours
Transport and unit operations	9 hours
Applied mathematics	5 hours

Reaction engineering/kinetics	3 hours
Control	3 hours
Design and economics	8 hours
Laboratory	5 hours
Senior seminar	1 hour

Most of the courses are based on standard chemical engineering texts, which are typically designed for three-hour courses. They contain both basic theoretical material and applications. Though the applications often contain a few selected topics from non-traditional areas, they are oriented primarily toward traditional large-scale, continuous chemical processes.

Material to be included as part of the core:

- *Material and energy balances and thermodynamics:* Combine the material from typical material and energy balance texts[5,6] and typical chemical engineering thermodynamics texts[7]. Eliminate duplicated material currently covered in both, such as common aspects of gas laws, vapor-liquid equilibria, heats of formation, heats of reaction, etc. Eliminate some of the more esoteric material from thermodynamics that is better covered in physical chemistry courses, such as statistical mechanics. What is left comprises a solid two-semester, six-hour sequence appropriate for the sophomore level.

- *Transport phenomena:* Cover the theoretical aspects of momentum, heat and mass transfer in a rigorous, four-hour course appropriate for the junior level. This assumes that students have learned some elementary fluid mechanics (e.g., Bernoulli's equation) and heat transfer (Fourier's law, radiation) in physics courses.

- *Reaction engineering/kinetics:* A two-hour course should be sufficient to cover the basics of simple reaction mechanisms and reactor models (PFRs, CSTRs and batch reactors) using material from existing texts[8,9].

Material to be reserved for specialty areas:

- *First-year introduction and senior and other seminars:* Do something that will really interest bright, young first-year students. Include them in special topic and research seminars along with graduate and upper class students. The first-year students may not understand everything, but they will grasp most of the material much faster than we give them credit. For the seniors, it can be a chance to consider seriously where they go next: industry, graduate school, other professional school, etc.

- *Material and energy balances and thermodynamics:* If appropriate to the specialty, include additional course work. For bio-oriented programs, this might include population dynamics. For materials-oriented programs it might include much more thorough study of solid-state phase behavior. For traditional chemical process programs, it might include more study of equations of state and phase equilibria.

- *Transport and unit operations:* For many decades the conventional wisdom in chemical engineering has been that a relatively small set of unit operations and processes could encompass all manufacturing systems a chemical engineer was likely to encounter. This no longer is the case. Specialty area courses should cover the unit operations and processes that are most important to that area. Students specializing in electronics materials processing don't need whole courses in distillation, absorption and extraction. They need to learn about crystal growth, photolithography, spin coating, etc. Similar comments apply to other specialty areas.

- *Reaction engineering/kinetics:* All specialty areas need to include additional reaction engineering material beyond what is covered in the core. For instance, all bio-oriented programs need to cover biological reaction mechanisms, some need to cover fermentors and other reactor designs, and some need to cover *in-vivo* reactions. Environment-based programs need to cover atmospheric reactions and reactions in groundwater.

- *Applied mathematics and computations:* There are mathematics topics that are of more importance to some specialty areas than to others. Design of experiments and statistical analysis are of high importance in the microelectronics and pharmaceuticals industries. ODE's and PDE's are of more importance in design of traditional process equipment and facilities and in environmental fields. Probability analysis is very important in health and safety fields. Each field has its own specific "industrial strength" computer program packages used for design, analysis and operations. Students should gain experience using the ones in their fields.

- *Design, economics, process control and laboratory:* These are all topics that have close ties to industrial and/or research laboratory practices. They can be very different, however, depending on what industry or research area they are tied to. The design process for a large-scale, continuous petrochemical plant is different from that of a microprocessor fabrication line or a pharmaceutical manufacturing plant. Likewise, the economics and regulatory requirements associated with these industries are very different, as are many of the control processes used in the plants. Over the years we have developed excellent courses to teach the design processes, economics and control methods for traditional plants, and we have usually required all chemical engineering students to take them. Except through elective courses, we have ignored the rest of the industries that hire our students.

We have not specified credit hours for the specialty area topics; they are likely to vary with the specialty topic as well as with the overall program at any particular school. We have, however, prepared a sample curriculum structure. Without making any other curriculum changes, 45 hours would be available in the University of New Mexico curriculum for specialty area courses and engineering electives. The current UNM chemical engineering curriculum and the sample core-and-specialty curriculum are given in tables in the Appendix. We have also identified specialty-area courses that could be appropriate for three different specialty-area tracks: traditional chemical process engineering, materials processing and biomolecular engineering. These are also listed in the Appendix. Although the sample curriculum allots the full 45 hours to specialty-area courses, we believe that the specialty area materials could be covered in considerably less than 45 hours, leaving room for some of the additional materials that we would like to include: communications, economics, business and management practices, foreign languages, etc.

Related issues

There are a number of student learning issues that should be considered in a possible curriculum change such as this one. We don't claim to know all the answers, but we don't believe there are any show-stoppers. These issues, of course, are not limited to new curricula; they apply equally to current curricula, though we may ignore them.

- *Deductive vs. inductive learning:* Despite the logical, deductive way in which many of we faculty members view our discipline, the majority of students are inductive learners; they learn basic principles only through extensive experience with examples. The common-core approach, with the most theoretical topics covered in a very compact fashion, could be too deductive for many students. This could be alleviated by careful structuring of parallel specialty area courses packed with examples.

- *Repetition:* For many students, once isn't enough, especially for material that is more abstract and theoretical. We already subconsciously acknowledge this in current curricula. Energy balances, in one form or another, are usually covered in courses in physics, chemistry, stoichiometry, engineering thermodynamics, reaction kinetics, and probably a few more places. Again, specialty area courses would have to include topics to reinforce what is covered in core chemical engineering courses and in science courses.

- *Team learning:* We have all learned that most students learn better when they work together to explore material and solve problems in small groups[10]. The common-core-plus-specialty approach lends itself to a great deal of team learning. Major portions of the specialty area could be covered through project-based learning involving teams made up of students from several different class levels. Care would have to be taken, however, to ensure that all students do meaningful work. Seniors can't just be bosses who make all the decisions; first-year students can't be just "gophers." And there is often a small portion of freeloaders. Overall, however, we believe that any disadvantages are more than outweighed by the advantage of having students work together on projects in which they are highly interested.

- *Textbooks:* The textbooks that most of us use are based on a traditional chemical engineering curriculum. The newer ones have a sprinkling of examples and problems from non-traditional specialty areas, but not enough to provide good coverage of any one area. There are some good one- or two-semester comprehensive texts in specialty areas, usually aimed at seniors and graduate students; but there are currently no texts or series of texts designed to cover the specialty in an integrated fashion throughout the curriculum.

- *Student Uncertainty:* Incoming students may not know what they want to specialize in. This is also a significant problem in our current curricula. A high school student performs well in math and science and hears that engineers make good salaries. As an entering first-year student, he or she signs up for chemical engineering. The reality at our almost-open-admissions university is that 70 to 80% of these students earn bachelors degrees at our university; 40 to 50% earn bachelors degrees in engineering; but only 35 to 40% earn bachelors degrees in chemical engineering. We believe that a significant part of this attrition is due to our not maintaining our students' interest. The majority of the incoming first-year students *think* they know what they would like to specialize in and want to learn about that specialty as soon as they can. The core-and-specialty area curriculum would permit much more course work of direct interest to the students throughout the program, including the first year. The downside, of course, is that students could have difficulty changing from one specialty area to another. Careful structuring of first-year and second-year courses could minimize, but not eliminate, this problem. We believe, however, that the advantages of maintaining student interest would outweigh the disadvantages incurred by some students.

The idea of offering BSChE degrees in specialty areas is not new. Most of us have been doing it for many decades, but by default we usually offered only one specialty area: the traditional chemical and petrochemical industry characterized by large-scale continuous processes. We do this because it's the way most of us learned, whether or not our current interests are in those fields, and because most textbooks are structured with this type of curriculum in mind. The job market, however, is much broader, and our students' interests follow their perceptions of the job market as well as their own views of productive, interesting careers. If we want to continue attracting students to chemical engineering programs, we must accommodate these changing interests and opportunities.

Given the large number of specialty areas within chemical engineering today, it is obvious that no school could possibly offer specialty programs in all of them. If the core and specialty approach is followed, each department would have to decide how many and which specialty areas it could effectively offer. Each department should then publicize what its areas are; we should not attempt to maintain the fiction that since chemical engineering now encompasses a wide range of specialties, every chemical engineering student in every chemical engineering department will be proficient in all of them. Smaller departments, in particular, would have to make some hard decisions. They would even have to advise some prospective students to enroll elsewhere. We already do this to a large extent in our graduate and research programs; why not in our undergraduate programs?

Conclusions

We have presented a possible new approach to structuring the BSChE curriculum to meet the needs of students preparing for careers in non-traditional areas: a twelve-semester-hour common chemical engineering core, coupled with applications, laboratories and design in a specialty area. The overall curriculum structure is not much different from most current curricula – except that there can be significant coverage of additional fundamental material and applications in non-traditional areas.

We believe the ideas presented here may be useful in encouraging discussion of new, innovative undergraduate chemical engineering curricula.

References

1. For instance, *AIChE Journal,* Vol. 50, Nos. 1 to 12, 2004.

2. For instance, *Chemical Engineering Progress*, Vol. 100, Nos. 1 to 12, 2004.

3. *2004-2005 Criteria for Accrediting Engineering Programs,* Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Inc., Baltimore, MD, 2004.

4. *Fundamentals of Engineering Reference Handbook, 6th Edition,* National Council of Examiners for Engineering and Surveying, Clemson, SC, 2003.

5. Felder, R.M., and R.W. Rousseau, *Elementary Principles of Chemical Processes, 3rd Edition,* John Wiley & Sons, Inc., 2000.

6. Himmelblau, D.M., and J.B. Riggs, *Basic Principles and Calculations in Chemical Engineering, 7th Edition,* Prentice Hall, 2004.

7. Elliott, J.R., and C.T. Lira, *Introductory Chemical Engineering Thermodynamics,* Prentice Hall, 1999.

8. Fogler, H.S., *Elements of Chemical Reaction Engineering, 3rd Edition,* Prentice Hall, 1999.

9. Levenspiel, O., *Chemical Reaction Engineering 3rd Edition,* John Wiley & Sons, 1999.

10. Felder, R.M., and R. Brent, "The Intellectual Development of Science and Engineering Students, Part 2: Teaching to Promote Growth," *Journal of Engineering Education,* Vol. 93, No. 4, 2004, pp 279-291.

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Appendix - Sample Curricula

Current University of New Mexico BS Chemical Engineering Curriculum

Fall Semester		Spring Semester	
FIRST YEAR			
Intro to Chemical & Nuclear Engr	1	Computer Programming	3
Calculus I *	4	Calculus II	4
General Chemistry & Lab I *	4	General Chemistry & Lab II	4
English Composition I *	3	English Composition II *	3
Humanities Elective *	3	General Physics I *	3
	15		17
SECOND YEAR			
Chemical Process Calculations I	3	*Chemical Process Calculations II*	3
Calculus III	4	*Thermodynamics*	3
Organic Chemistry & Lab	4	Applied Ordinary Differential Eqs	3
General Physics II	3	Advanced Chemistry #	4
Intro Macroeconomics *	3	Science Elective #	3
	17		16
THIRD YEAR			
Intro Transport Phenomena	4	*Chemical Engr Thermodynamics*	3
Chemical/Nuclear Engr Applied Math	3	*Unit Operations*	2
Chemical/Nuclear Engr Economics	3	*Mass Transfer*	3
Technical Writing *	3	Engineering Elective	3
Advanced Chemistry #	4	Advanced Chemistry #	4
		Humanities Elective *	3
	17		18
FOURTH YEAR			
Chemical Engr Lab I	2	*Chemical Engr Lab II*	3
Chemical Engr Senior Seminar	1	*Process Dynamics & Control*	3
Chemical Reactor Engr	3	*Advanced Chemical Engr Design #*	2
Chemical Engr Design	3	*Technical Elective #*	3
Technical Elective #	3	Fine Arts Elective *	3
Social Science Elective *	3	Second Language Elective *	3
	15		17
		Total Credits	132

Chemical engineering courses in Italics
Offers chance for specialization
* Meets UNM core requirement

Possible Core-and-Specialty Chemical Engineering Curriculum

FIRST YEAR

Fall Semester		Spring Semester	
Specialty Area Seminar #	1	*Specialty Area Seminar #*	1
Calculus I *	4	*Intro to Specialty Area I #*	2
General Chemistry & Lab I *	4	Calculus II	4
English Composition I *	3	General Chemistry & Lab II	4
Humanities Elective *	3	English Composition II *	3
		General Physics I *	3
	15		17

SECOND YEAR

Fall Semester		Spring Semester	
Specialty Area Seminar #	1	*Specialty Area Seminar #*	1
Mat'l & Energy Balances & Thermo	3	***Mat'l & Energy Balances & Thermo***	3
Intro to Specialty Area II #	2	*Specialty Area Course #*	3
Calculus III	4	Applied Ordinary Differential Eqs	3
Organic Chemistry & Lab	4	Advanced Chemistry #	4
General Physics II	3	Science Elective #	3
	17		17

THIRD YEAR

Fall Semester		Spring Semester	
Specialty Area Seminar #	1	*Specialty Area Seminar #*	1
Transport Phenomena	4	***Intro Reaction Engineering***	2
Specialty Area Applied Math	3	*Specialty Area Unit Operations #*	4
Specialty Area Mat'l & Energy Balances	2	*Specialty Area Course #*	3
Technical Writing *	3	Advanced Chemistry #	4
Advanced Chemistry #	4	Social Science Elective *	3
	17		17

FOURTH YEAR

Fall Semester		Spring Semester	
Specialty Area Seminar #	1	*Specialty Area Seminar #*	1
Specialty Area Reaction Engr #	2	*Specialty Area Lab & Design #*	4
Specialty Area Lab & Design #	4	*Specialty Area Senior Project #*	5
Specialty Area Course #	3	Fine Arts Elective *	3
Social Science Elective *	3	Second Language Elective *	3
Humanities Elective *	3		
	16		16
		Total Credits	132

Chemical engineering core courses in bold Italics

 # Specialty area chemical engineering courses in italics

* Meets UNM core requirement

Possible Courses for Three Specialty Areas

Traditional Chemical Process Engineering	Materials Processing	Biomolecular Engineering
Advanced chemistry:	Advanced Chemistry:	Advanced Chemistry:
Organic Chemistry & Lab II	Physical Chemistry I	Organic Chemistry & Lab II
Physical Chemistry I	Physical Chemistry II	Physical Chemistry I
Physical Chemistry II	Advanced Inorganic Chemistry	Biochemistry
Science elective:	Science elective:	Science elective:
General Physics III	General Physics III	Cellular and Molecular Biology
Specialty area courses:	Specialty area courses:	Specialty area courses:
Intro Materials Science	Intro Materials Science	Biomolecular Engr Fund'tls
Unit Operations & Lab	Reactor Engr for Mat'ls Processing	Bioreactor Engineering
Mass Transfer	Transport in Materials	Separation in Biotechnology
Process Control	Materials Characterization	Biomolecular Engr Lab
Catalysis and Reaction Engr	Materials Processing Lab	Biomed Technology
Plant Design Project I	Design Project I	Biochemical Process Design I
Plant Design Project II	Design Project II	Biochemical Process Design II