Frontiers in Chemical Engineering Education

New Directions and Opportunities – Creating the Future

CCR/NSF Discipline Wide Curriculum Workshops

Workshop III
The Path Forward

My Vision

- An exciting new curriculum that
  - builds on our unique position in engineering
  - attracts the best and brightest undergraduates into our profession
  - is highly valued by industry
  - contains a wealth of fresh, renewable
    - examples
    - laboratories,
    - projects

    contributed and shared by the whole community
  - uses best practices for teaching

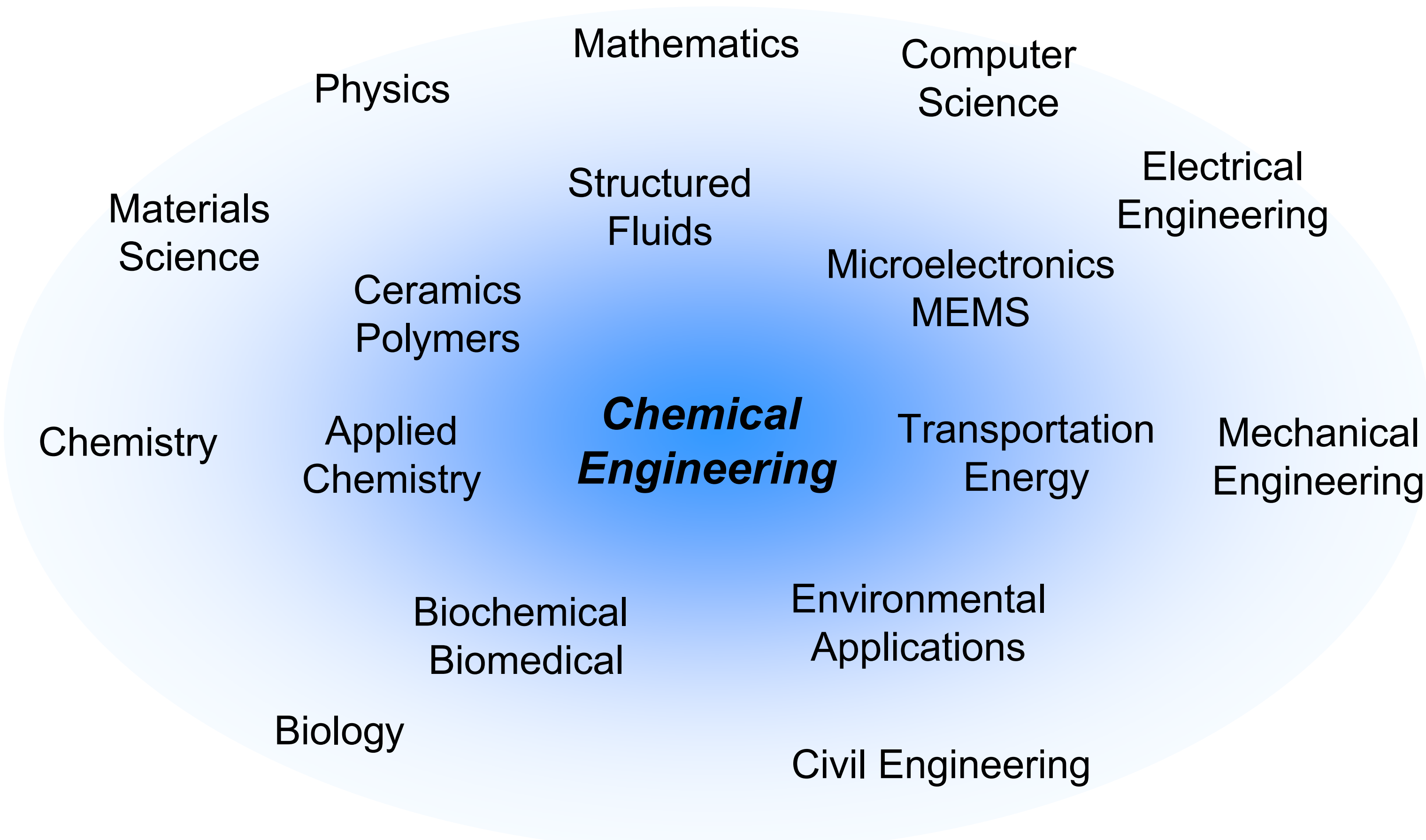
Why Cooperate?

- The opportunities/frontiers are too broad for any one or several departments to address effectively
- The costs – time and money – of developing new educational materials are too high for any of us to absorb alone
- The coherence resulting for a joint effort will serve the discipline well
  - Maintain clear identify to the world (potential students, industry, government)
  - Ensure good manpower supply to industry and to our graduate programs
  - Ensure that curriculum developments are used

NSF/CCR Curriculum Grant

- The time is right for new curriculum focus
  - Need to incorporate molecular and cellular biology appropriately as underlying science
  - Need to connect students to the many applications of chemical engineering
  - Methods of engaging students in classrooms and laboratories are being reexamined and methods of incorporating new technology for education need to be incorporated
- New curriculum needs to be discipline wide
  - Common core has been a strength of the discipline
  - Richer curriculum results from broad array of examples, texts, modules, ….

Chemical Engineering at the Center



Chemical engineering has a unique position at the interface between molecular sciences and engineering

Who Are We?

- Molecular transformations
- Multiscale understanding
- Systems view
- Quantitative approach

We need to build on these while maintaining

- Well defined, common core
- Close, active connection with science
- Relevance to industry

Drivers for Change

- Biology represents a new frontier for us as a discipline
  - Advent of molecular biology and its incorporation into biochemistry, genetics, and cell biology make biology a natural science for chemical engineering
- Our close connection with basic science makes our graduates very versatile
  - We have failed to articulate this clearly to our stakeholders
  - We have failed to imbed this in our curriculum
- Our traditional industry has shifted
- Our student base is at risk

Challenges for Our Curriculum

- Need to integrate biology appropriately as a basic science for our discipline
- Need to balance the tension between diversity in research application areas and a coherent, strong core
  - Molecular transformations, quantitative understanding, systems treatment, multiscale analysis
- Need to balance the desire to teach many specific topics vs. using these to educate students for the future
- Need to balance applications with fundamental knowledge, synthesis with analysis
- Need to attract the best and brightest young minds into our discipline
  - Need to project an accurate, exciting image of our discipline to students/employers

NSF/CCR Workshops

- Lead to large NSF proposal to fund development
  - These proposals are for discipline wide efforts
  - Our joint proposal will use talents, time, resources nationally
- Help foster connections between individuals and institutions
- Workshop 1 – Building Blocks of the Future
  - What is the essential ***intellectual*** content of our future educational program
  - Not subject titles or semester blocks
  - Ideas, skills, knowledge, ….
  - Involve individuals deeply interested in undergraduate education
  - Identify specialists for the next workshop

NSF/CCR Workshops

- Workshop 2 – Topic Development
  - Detailed content (knowledge, skills, attributes, …) of the bocks
  - Interconnections among these components
  - Identify gaps and opportunities; disconnected pieces
  - Involve experts in the different topical areas
- Workshop 3 – Integration
  - How do we assemble the components into an exciting, engaging, adaptable educational program?
  - Involve educational experts
  - Plan for proposal to develop curriculum components

Out of the Box Thinking

- Principles:
  - Education is preparation for life: it is more than intellectual development;
  - The value of fundamentals: a technical or professional education should be based on fundamental principles;
  - Excellence and limited objectives: fit to needs of society, fit to concern with science and technology, fit to our unique disciplinary core.

B.F. Skinner: "Education is what survives when what has been learned has been forgotten."

Workshop 1 – Common Themes

- Biology is a foundation science
- Agreement that the need for change goes beyond biology
  - Diversity of employment
  - Public perception
  - Recognition of molecular-level understanding
  - Competition for best students
- Need to engage enabling sciences in change
- Infuse curriculum with contemporary examples that integrate principles of chemical engineering
- Chemical engineering involves analysis, design, and synthesis

Common Themes continued

- Need to articulate to freshmen the intellectual challenges and professional opportunities
- Chemical engineering includes multi-scale descriptions of materials and phenomena
- Agreement on the desired attributes of the chemical engineering graduate
  - Experience in labs
  - Communication skills
  - Problem solving skills
  - Etc …
- Curriculum should be designed for flexibility

Building Blocks – Areas of Agreement

- The enabling sciences are:
  - biology
  - chemistry
  - physics
  - math
- There is a core set of chemical engineering principles
- Molecular level design is a new core principle
- Chemical engineering contains both product & process design
- There is a need for 1st year chemical engineering experience

Building Blocks

- Proposals
  - case study learning
  - vertical integration
  - molecular-level design as an organizing principle
  - single-room learning
- Other Ideas
  - benefits of alternative terminology in curriculum revitalization
  - student as a customer (or partner, employer as partner, participant, constituent, ally)

Summary Report on Curriculum Ideas

Jim Rawlings
Mike Thien

Conclusions Regarding the Chemical Engineering Profession...

- The chemical engineering profession is very successful
  - has moved in many new directions, pushing the understanding and use of new technologies
  - students are highly sought after by industry
  - this has been made possible by the effective teaching of the fundamentals of chemical engineering

… however...

- Chemical Engineering is facing significant pressure from other disciplines

and

- The Current Curriculum is not well integrated:
  - it is compartmentalized in the subjects presented
  - "tired"
- The Current Curriculum is largely ***<u>not</u>****:*
  - exploring transformations at the molecular level
  - embracing complexity and uncertainty
    - closed problems with one answer
  - demonstrating the applicability of multiple scales
  - demonstrating/effectively using systems approaches
  - employing relevant, interesting and topical examples to illustrate principles

Integration of the Curriculum: New Core Organizing Principles

- Molecular Scale Transformations
  - chemical & biological
  - physical: phase change, adsorption, etc
- Multi-Scale Descriptions
  - from sub-molecular through “super-macro”
  - for physical, chemical and biological processes
- Systems Analysis & Synthesis
  - at all scales
  - tools to address dynamics, complexity, uncertainty, external factors

Old core does not integrate molecular concepts

Old core covers only macro to continuum, physical and chemical

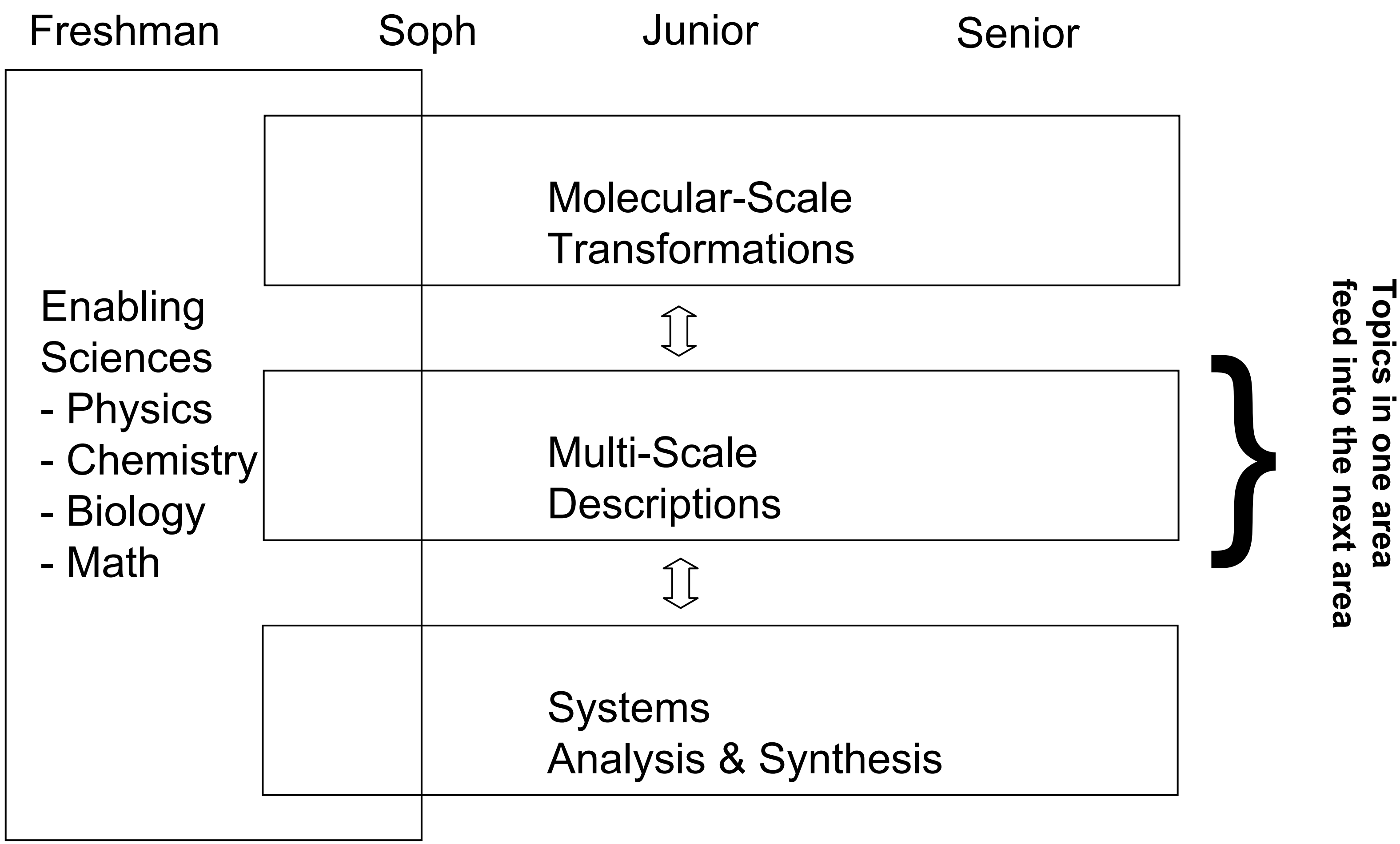
Old core primarily tied to large scale chemical processes

Creation of the New Curriculum: Essential Elements

- Case Studies and Examples
  - Diverse
  - Relevant and topical
  - Integrated into curriculum
    - horizontal integration (over time)
    - vertical integration (between classes at same time)
  - Provide real world context
    - safety, economics, ethics, regulation, IP, market/social needs
  - Provide real world challenge
    - open-ended, complex, incomplete data, rapid generation, and pruning alternatives

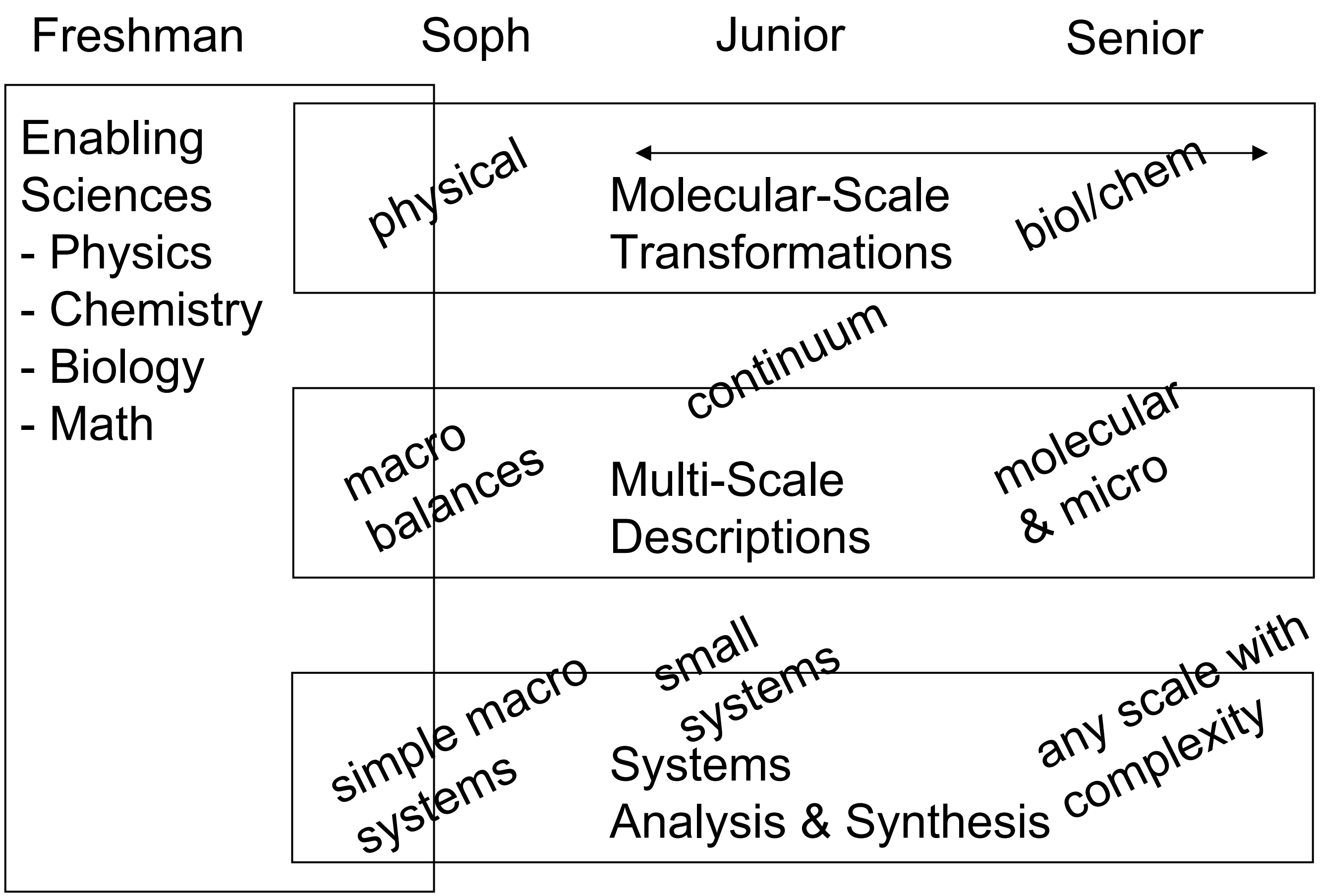
...Essential Elements... (cont.)

- Integrated Curriculum



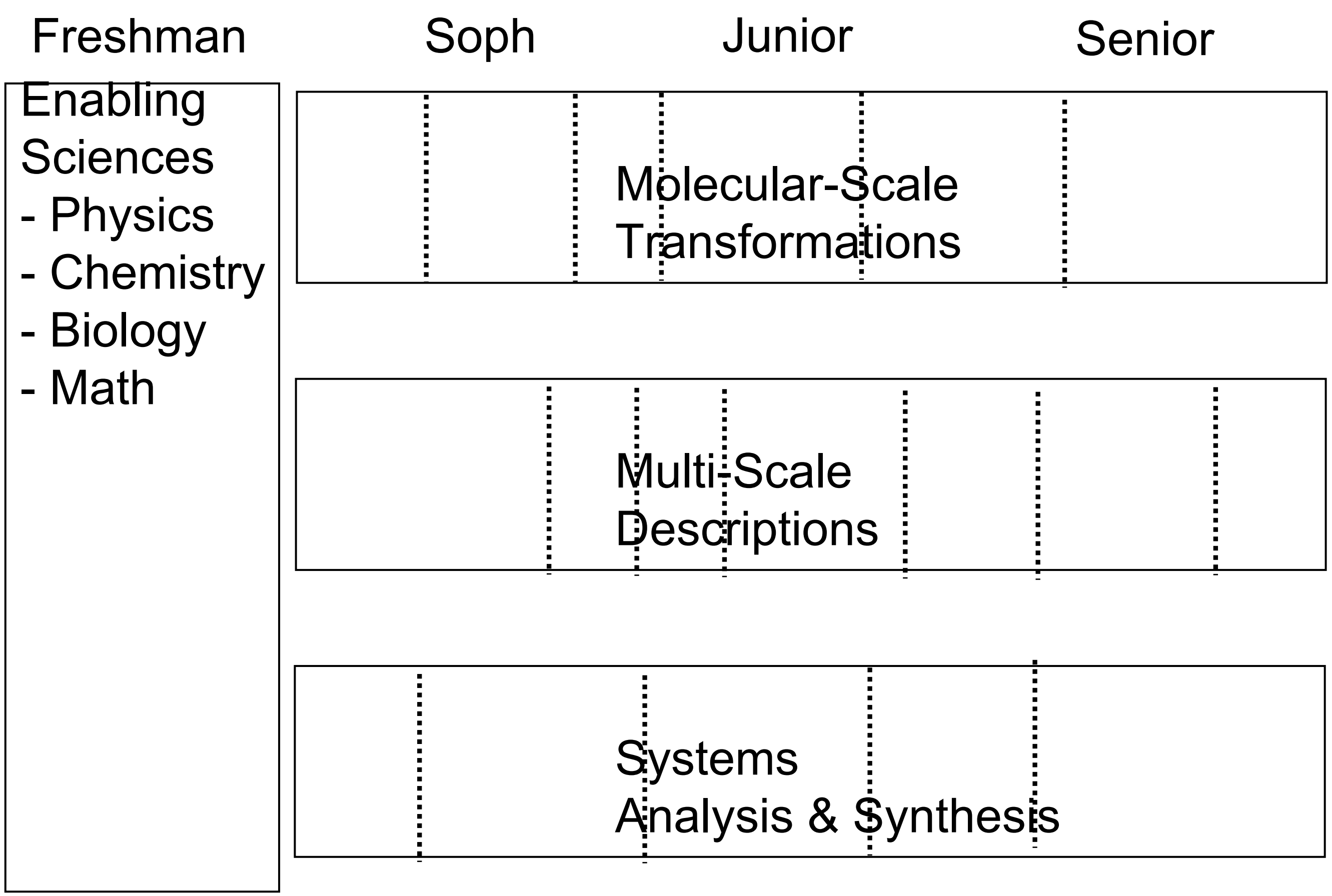
...Essential Elements... (cont.)

- Integrated curriculum: incorporating the fundamentals



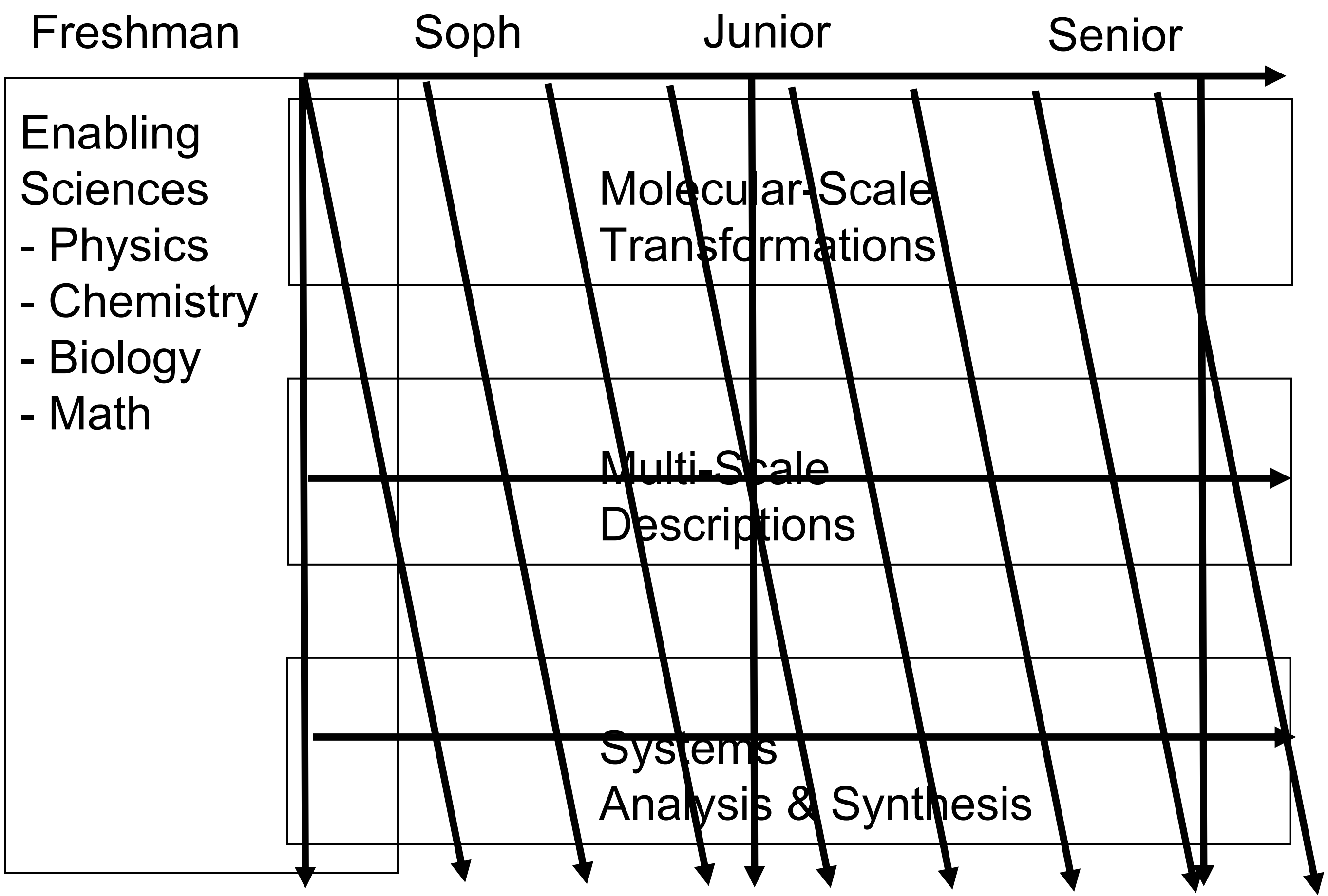
...Essential Elements… (cont.)

- Integrated curriculum: incorporating modules



...Essential Elements... (cont.)

- Integrated curriculum: incorporating examples



The Spectrum of Curriculum Change: from "Tweaks" to "Complete Overhaul"

- The consensus is that we seek large change
  - the science base has dramatically increased
  - this creates new economic opportunity
  - some discipline will emerge to address these new opportunities
  - chemical engineering is well-positioned to be this new discipline...
  - …but it will require a large change to the undergraduate curriculum
- This change may require a 10 year investment
- We must accommodate a diversity of universities

Additional Discussion

- Integrating case studies/examples emerge as an important theme
  - Better enable teaching of critical attributes such ability to think critically, to work effectively with uncertainty, to continue to learn beyond the classroom, ….
  - Connect better with evolving industries and research frontiers
  - Reopen the flow of ideas from graduate research to the undergraduate curriculum

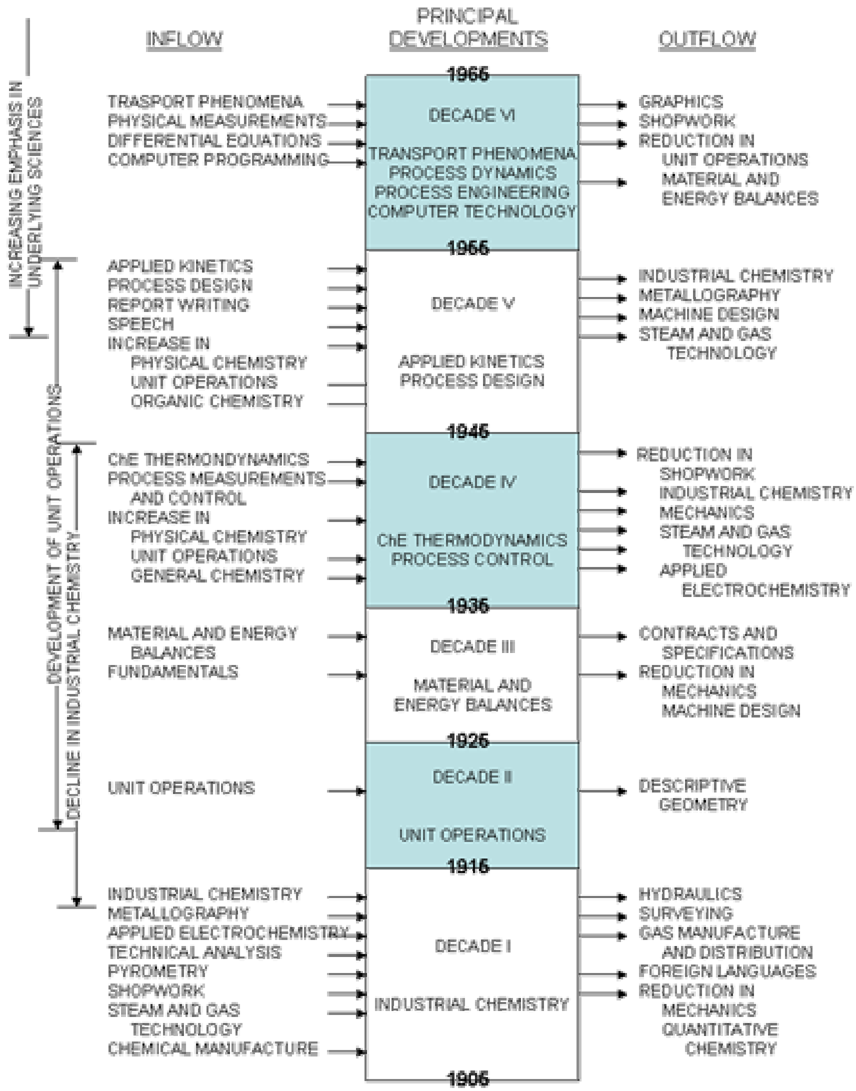
…but

- Should we also do this with laboratory subjects/experience
- How do we teach faculty to do this? (or is this not a problem)
- How do we distribute these?
- How do we ensure uniformity/interoperability?
- How do we provide incentives for initial and ongoing work?
  - Credit for contributions
  - Financial incentives – replace book royalties(?!)

Workshop III

The Path Forward

- A plan for the coming decade
  … Hougen chart revisited



Changes in a typical undergraduate chemical engineering curriculum during 60 years. The initial curriculum in 1905 consisted of separate courses in chemistry and conventional engineering.

The Coming Decade

Increasing emphasis in biology and integration

INFLOW	PRINCIPAL DEVELOPMENTS	OUTFLOW
Molecular engineering Systems analysis Biology …	2015 DECADE XI Molecular Transformations Multiscale analysis Systems view Quantitative treatment 2005	Units ops labs Separations …

A Large Change is Needed

- A plan for change
- Proposal to NSF is just the first step
- Need to develop “document” that discipline can use as a rallying point for education
- Need to engage our profession more fully – AIChE?
- Need to engage industry more fully
- Need to communicate to the public
  - Public perception
  - Attract the best students
  - Clarify to stakeholders the nature of our graduates
- How do we best bring new educational methods/technology to our faculty

Proposal

- Motivation
  - Drivers for change in chemical engineering
  - Educational frontiers for chemical engineering
- Overview of curriculum
  - Goals
  - Structure
  - Versatility
- Proposed curricular development
- Mechanisms for interoperability and sharing
- Use of best practices in teaching
- Evaluation and assessment
- Summary and conclusions

Proposed Curricular Development

- Topics
  1. Molecular tranformations
  2. Multiscale
  3. Systems
  4. Supporting classes
  5. laboratories
  6. Gap/bridge team

Proposed Curriculum Development

- How do we manage this?
  - Get faculty time – not do this on the margins
    - Money is probably easier than time
  - Target teams to ensure integration (molecular, multiscale, systems)
  - How do we ensure full coverage – address gaps
  - Ensure quality control
  - Time scale
    - Proposal to NSF due July 7 (?)