Summary of Workshop III

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What this is. What this is not.

- What this is: A proposed consensus summary of the activities of this workshop

- What this is not: A vehicle for presentation outside the context of the workshop

Basic Tenets of the New Curriculum

- Changes in science and the marketplace call for extensive changes to the Chem Eng curriculum
  - see notes from Workshops I & II
- The enabling sciences are: biology, chemistry, physics, math
- There is a core set of organizing chemical engineering principles
  - Molecular Transformations, Multi-scale Analysis, Systems
    - Molecular level design is a new core organizing principle
- Chemical Engineering contains both Product and Process Design
- There is agreement on the general attributes of a chemical engineer

Ingredients of the New Curriculum

- The curriculum should integrate all organizing principles and basic supportive sciences throughout the educational sequence
- All organizing principles should be operative in the curriculum throughout the sequence and should move from simple to complex
- The curriculum should be consistently infused with relevant and demonstrative laboratory experiences
- Opportunities for teaming experiences and use of communications skills (written and oral) should be included throughout the curriculum

Ingredients of the New Curriculum

- The curriculum should address different learning styles

- The curriculum should be consistently infused with relevant and demonstrative examples
  - open-ended problems and case studies
  - challenges of engineering practice: safety, economics, ethics, regulation, IP, market/social needs

- The curriculum should include a first year chemical engineering experience

A “First Draft” Curriculum

Supporting Courses from Other Departments

- Physics
  - intro mechanics, E&M, Biophysics, Solid State
- Chemistry
  - general chemistry + 1 semester Organic Chemistry
  - physical chemistry: quantum, spectroscopy, analytical techniques
- Biology
  - biochemistry, molecular & cellular biology
- English/Humanities: communications skills, ethics
- Math: Calculus, Matrices, ODE's
- Materials Science
- Management/ Business

The Freshman "Experience"

- Molecular Transformations
  - introduction to molecular structure-property correlations
- Multi-scale Analysis
  - scaling laws
  - dimensional analysis
  - impact of micro events on macro phenomena
- Systems
  - plantwide and product viewpoints
  - degrees of freedom analysis
- Lab
  - spheres of different sizes and densities falling through fluid (dim analysis)
  - hydrophobic vs hydrophilic coating on sphere surface, solutes that affect viscosity
  - numerical model, optimization and making of a sphere that will drop in specified time

Molecular Transformations

- Molecular transformations: the molecular basis of chemical engineering
  - goals: students recognize that properties can be changed by changing structure via qualitative and quantitative computation
- Molecular Basis of Thermodynamics (Sophomore)
  - intro quantum & stat mech, ideal gas heat capacities, molecular/stat mech basis of entropy, equilibria, 1st Law, 2nd Law, equations of state, heat of vaporization, phase transitions
- Classification of Molecules (Sophomore)
  - qualitative concepts (“hydrophilic”, “hydrophobic”), quantitative structure-property correlations, different types of molecules, macromolecules, high-specificity biological interactions
- Molecular Basis of Reaction Rates (Sophomore or Junior)
- Molecular Basis of Other Properties & Constitutive Equations (Junior)
  - transport properties, effects of polymer/biomolecular conformations, mixture properties, some elements of molecular biology
- Special Topics (Junior/Senior electives)
  - interfacial phenomena, nucleation/growth, material props, directed evolution

Multi-Scale Analysis

- Multi-scale analysis: Application of chemical engineering principles over many scales of length and time
- Interfaces and Assemblies (Sophomore)
  - adsorption, extraction, interfaces, Brownian motion, DLVO, nucleation, colloidal interactions, molecular assemblies
- Homogeneous Reactor Engineering (Sophomore)
  - PFR and CSTR
- Multi-scale descriptions of reactive systems (Junior)
  - Integrated approach to continuum momentum, heat and mass transfer with reactivity
  - stochastic processes
  - heterogeneous systems and interfacial phenomena
  - separations
  - advanced assemblies
- Beaker-to-Plant: Implementation of Multi-scale Principles for Product and Process Design (Senior)
  - design of a product and process to make the product: polymer, drug delivery system (includes lab component for making of prototype)
  - tie-in with “Systems and the Marketplace”?

Systems

- Systems: tools for synthesis, analysis and design of processes, units and collections thereof
- Introduction to Systems (Sophomore)
  - conservation laws for simple dynamic and steady state systems, build model for experimental dynamic system, collect and analyze lab data, build numerical simulation, parameter estimation (exposure to complexity and uncertainty), construct equipment/sensor
- Introduction to Molecular Systems (Junior)
  - stochastic systems and molecular level reactions as systems
  - simulation as an enabling technology
  - optimization principles for design, parameter estimation and decision-making
  - examples from microelectronics, catalysis, systems biology, stochastic kinetics
- Systems and the Marketplace (Senior)
  - multi-scale systems: separation and resolution of time and length scales
  - design and analysis of feedback
  - monitoring, fault detection and sensitivity analysis
  - design experience: economics/business skills, safety, marketing, environmental impact, life cycle analysis, ethics, globalization, IP

Laboratory

- Includes VLAB, ILAB and hands-on
- Will teach:
  - teamwork & communication skills
  - ability to handle real (i.e.messy) problems and data
  - open-ended problem solving
  - safety
  - environmental & regulatory issues
  - reinforcement and visualization of concepts from courses
- Can also teach
  - experimental design
  - new concepts
  - basic lab techniques and instrumentation

Integrated Curriculum

Freshman | Soph | Junior | Senior

Enabling Courses

- Physics
- Chemistry
- Biology
- Math
- Mat'ls Sci
- Eng/Comm
- Bus/Mgt

Chem Eng: The Frosh Experience

Molecular-Scale Transformations

Soph	Junior	Senior
Molecular Basis of Thermo Classfctn of Molecules	Molecular Basis of Reactions Molecular Basis of Properties and Constitutive Eqns	Special Topics (Electives)

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Multi-Scale Analysis

Soph	Junior	Senior
Interfaces and Assemblies Homogeneous Reactor Eng	Multi-Scale Descriptions of Reactive Systems	Beaker to Plant: Principles of Product & Process Des.

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Systems

Soph	Junior	Senior
Intro to Systems	Intro to Molecular Systems	Systems & The Marketplace

Concerns

- Will the student outcomes be demonstrably improved?
- Can we build consensus in the profession for this large change?
- Timely implementation and quality control for such a large change over a widely disparate distribution of schools and resource bases?

Path Forward

- Build consensus and obtain critical feedback from both academia and industry
- Prepare the new educational materials
  - marshal the necessary resources
  - develop oversight and management plan
- Plan for deployment and assessment

Final Thoughts

- These three workshops have taken the participants on an introspective “journey”
  - We have asked and answered: What is an education in chemical engineering? Why is it important? What value does it add?
- We have been willing to look ahead and develop a *new* and creative vision for our future students
- The consensus for this framework for change is strong
- We should be bold in implementation

Appendix

Sophomore Year

- Molecular Transformations: Molecular Basis of Thermodynamics
  - intro quantum & stat mech, ideal gas heat capacities, molecular/stat mech basis of entropy, equilibria, 1st Law, 2nd Law, equations of state, heat of vaporization, phase transitions
- Molecular Transformations: Classification of Molecules
  - qualitative concepts (“hydrophilic”, “hydrophobic”), quantitative structure-property correlations, different types of molecules, macromolecules, high-specificity biological interactions
- Molecular Transformations: Molecular Basis of Reaction Rates
- Multi-Scale: Interfaces and Assemblies
  - adsorption, extraction, interfaces, Brownian motion, DLVO, nucleation, colloidal interactions, molecular assemblies
- Multi-Scale: Homogeneous Reactor Engineering
  - PFR and CSTR
- Systems: Introduction to Systems
  - conservation laws for simple dynamic and steady state systems, build model for experimental dynamic system, collect and analyze lab data, build numerical simulation, parameter estimation (exposure to complexity and uncertainty), construct equipment/sensor

Junior Year

- Molecular Transformations: Molecular Basis of Reaction Rates
- Molecular Transformations: Molecular Basis of Other Properties & Constitutive Equations
  - transport properties, effects of polymer/biomolecular conformations, mixture properties, some elements of molecular biology
- Multi-scale: Descriptions of reactive systems
  - Integrated approach to continuum momentum, heat and mass transfer with reactivity
  - stochastic processes
  - heterogeneous systems and interfacial phenomena
  - Separations
  - advanced assemblies
- Systems: Introduction to Molecular Systems
  - stochastic systems and molecular level reactions as systems
  - simulation as an enabling technology
  - optimization principles for design, parameter estimation and decision-making
  - examples from microelectronics, catalysis, systems biology, stochastic kinetics

Senior Year

- Molecular Transformations: Special Topics (electives)
  - interfacial phenomena, nucleation/growth, material props, directed evolution

- Multi-Scale: Beaker-to-Plant- Implementation of Multi-scale Principles for Product and Process Design
  - design of a product and process to make the product: polymer, drug delivery system (includes lab component for making of prototype)
  - tie-in with “Systems and the Marketplace”?

- Systems and the Marketplace
  - multi-scale systems: separation and resolution of time and length scales
  - design and analysis of feedback
  - monitoring, fault detection and sensitivity analysis
  - design experience: economics/business skills, safety, marketing, environmental impact, life cycle analysis, ethics, globalization, IP

Multi-Scale Analysis

Dimension/Year	Freshman	Sophomore	Junior	Senior
What's taught	Scaling laws Dimensional Analysis Impact of Micro events on macro-phenomena	Interfaces and Assemblies - Adsorption & Extraction - Interfaces - Brownian Motion - DLVO - Nucleation theory - Colloidal interactions - Molecular Assemblies Homogeneous Reactor Engineering - incl PFR, CSTR	Multi-Scale Descriptions for Reactive Systems - Continuum: integrated approach to continuum momentum, heat and mass phenomena for chemically reactive systems - Micro-Macro/Stochastic - Heterogeneous systems - interfacial transport - Advanced assemblies	Beaker to Plant: Implementation of Multi-scale Principles for Product and Process Design
What's brought in	Simple conservation laws	Molecular interactions Physical Property Estimation	Molecular reactivity	
Types of problems	Wave speed on ocean Pendulum swing Settling velocity of sphere and influence of scale Swimming organisms Impact of scale on epidemics and their impacts on populations (native Americans)	RSA "Migration" - Electrophoresis - Chemotaxis - Blots Liposomes Rou Laux (blood cell aggregate) Atmospheric aerosols Cells Atmosphere Atmospheric totality Microelectronics	Complex flows w/ & w/out reaction Catalytic reactor design - Chemical - enzymatic Cell culture and Fermentation Microelectronics fabrication Staged operations - distillation, chromatography, etc	Design and Delivery of a Drug Polymer Product and Process Design
Lab Expts	Settling of a sphere in a tube - fluids - drag-reducing fluids Sexy expt (TBA: Lab Group)	Micro-reactor Flocculation Nano-particles for Drug Delivery	CFD Enzyme reactor Flow Visualization	Making the Product