## Session 3: approaches to a curriculum
## Wednesday afternoon, 2003 April 9

Workshop participants were divided into four new working groups, each charged with the same question: how to present the knowledge base of chemical engineering as a sequence of experiences that comprise an undergraduate curriculum, in a way that cultivates the desired attributes of the graduate and integrates the knowledge base into a useful whole. Their reports are presented below.

### The "A TEAM"

Anuj Chauhan
Steven Chuang
Kenneth Hill
Joe McCarthy
Greg McRae
Bill Miller
Michael Prudich
Fred Weber

NSF Curriculum Workshop, April 9, 2003, Austin, TX

### Discussion Themes – *Issues*

- **Market for graduates** – *Where will they go?*
- **Attributes and Experiences** – *What personal skills?*
- **Knowledge and Experiences** – *What do they know?*
- **Organization Models** – *How to implement ideas?*
- **Implementation** – *How do we get it done?*
- **Delivery** – *Mode of teaching?*

***Note: curriculum revision concepts should not be confined solely to chemical engineering departments***

### Markets for our Graduates

**Industries**

- Petrochemical
- Pharmaceutical/Biotech
- Medicine
- Microelectronics
- Finance/Consulting
- Start their own companies
- Many careers over a lifetime

*Field is diverse and continuing to evolve*

### Attributes and Experiences Needed for Success

*Be able to:*

- Structure and solve complex problems
- Appreciate the need for fundamentals
- Cope with missing data/information
- Work in teams
- Appreciate market forces and social contexts

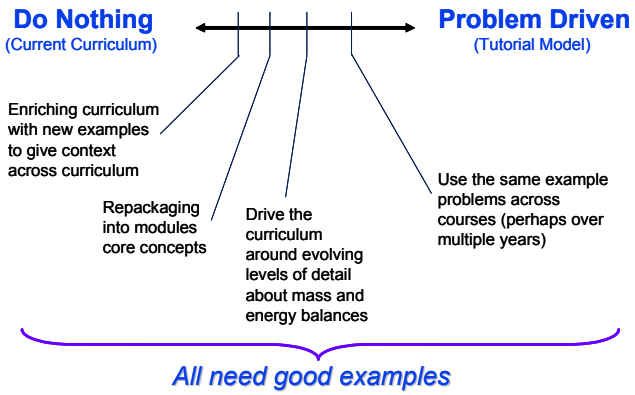
## Knowledge and Experiences Needed for Success

*Facility with*

- Fundamentals (Phys/Chem/Bio/Math)
- Mass and energy balances
- Thermodynamics
- Transport
- Safety
- Systems engineering
- Finance/Business economics

*Multiscale, molecular viewpoint and integration*

## Organization Models for Curriculum




## Problems

***Examples that have potential to illustrate: social context, integration concepts, multiscales and molecular viewpoints***

- Hydrogen economy
- Global climate, air pollution
- Microelectronics
- Biomedicine
- Water purification (e.g. desalination)
- Gene therapy
- Design and development of composites
- Vaccine and drug production/delivery

## Example Module: Chemical Processes in the Human Body

- Blood flow (Fluids)
- Pharmacokinetics (Kinetics/Thermodynamics)
- Thermal regulation (Heat/mass transfer)
- Drug delivery (Molecular processes)
- Artificial organs (Systems engineering)
- Metabolism (metabolic pathways)
- Cell to organ (Multiscale processes)
- Cancer growth (Control systems)
- Medical data (Statistics/data acquisition)

## Next Steps – Key Questions

- How to capture/build on results of ongoing curricula redesign experiments?
- How to organize the construction of “examples”?
- How to measure success?
- How to get faculty buy in?
- What form should the proposal to NSF/ Foundations/Industry take?

## Delivery Mechanisms

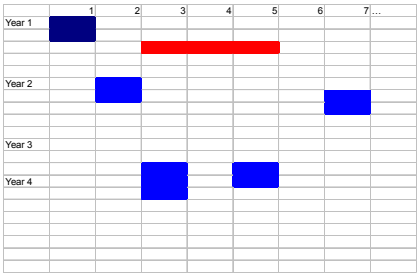
- University of Phoenix (Electronic)
- Web (MIT Open Courseware Initiative)
- Traditional (Chalk/Talk)
- Etc.

*This is an important issue and needs additional discussion, with educational experts*

## B Team

- Ted Wiesner
- Dick Turton
- John Gossage
- Graham Harrison
- Tom Edgar
- Duane Johnson
- Bridget Rogers
- David Hackleman

## Vertical vs Horizontal Integration




# Project Module Approach

- Key Elements of ChE
  - Understand System Globally
  - Synthesis of information
  - Problem Definition
  - Teamwork
  - Transport
  - Industrial Content
  - Economics
  - Safety
  - Environmental
  - Molecular Configuration
  - Kinetics
  - Thermodynamics
  - Lab Experience
  - Material/Energy Balance
  - Material Properties
  - Control
- Drug Patch (Example)
  - Simple
  - Necessary
  - Fits
  - Not required (but possible)
  - Diffusion Transport (Bio)
  - Optional
  - Possible
  - Possible
  - Possible
  - Learn Shapes and Size Effects
  - CSTR (Blood = Drug)
  - ?
  - Diffusion Experiment
  - Unsteady State Process
  - Adhesive-Skin, Polymer effusion binder
  - Rate limiting difusion

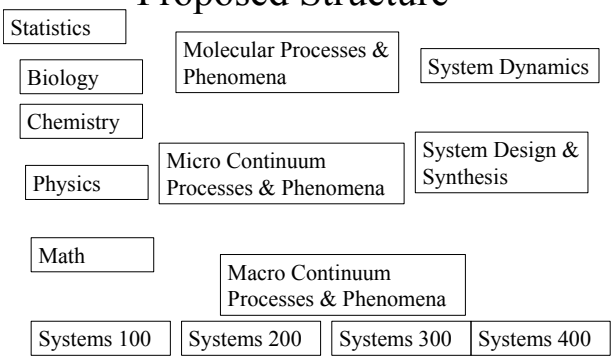
## Project Modules

- Introduce 4 or 6 examples
  - start at beginning of curriculum
  - use no more than 5% of instructional time
  - Come up with 1-3 new examples each year
    - Create the AIChE Examples Group!
      - Relevant project worthy examples
      - Industry Advisory (Advisory Boards) Input

## Current ChE Courses

- **Thermo**
- **Fluids**
- **Heat**
- **Mass/Separations**
- **Reaction Engineering**
- **Control & Process Dynamics**
- **Design**
- **Unit Ops**
- **Engineering Economics**
- **Chemical Engineering Math**
- **(Materials Science)**

## Proposed Structure




## Molecular Processes & Phenomena

- Probability & Statistics
- Stochastic processes/Stat. Mech
- Molecular Structure (organic, inorganic,bio)
- Intermolecular forces (molecular interactions)
- Molecular dynamics
- Thermo (pieces)
- Kinetics
- Numerical Methods

## Micro Continuum Processes

- Differential Conservation laws
- Constitutive relations
- ODE's
- PDEs
- Classical Thermodynamics (pieces)
- Mass, Heat, & Momentum Transfer
- Vectors & Tensors

## Macro Continuum Processes

- Macroscopic conservation laws
- reactor analysis & design
- process dynamics
- unit operations
- separations

## Systems

- Solutions of simutaneous equations (algebraic, differential)
- cross-scale integration
- Process Control
- Economic Analysis
- Process synthesis & Design
- Creativity techniques
- Environmental considerations
- Safety Considerations
- Optimization

## SOFT SKILLS

- Oral Communication
- Written Communication
- Graphic Communication
- Team Skills
- Creativity techniques
- Problem Solving Skills

## Group C

**Chris Brazel**
**Ramon Cerro**
**John Eckert**
**Bill Olbricht**
**Jim Rawlings**
**Mike Thien**
**Ted Watson**

## Module Names *

- Dynamics and feedback (incl. Complex systems)
- Molecular forces to macroscopic properties
- Dynamics of molecular aggregates
- Transient processes
- System and parameter identification
- Organizations of complex systems
- Rate and equilibrium separations
- Unified balances
- Synthesis of products and processes
- Engineering physical chemistry (nano)
- Interfaces
- From beaker to Process
- Professional Chemical Engineering
- Dynamics of Molecular Transformations

**All include aspects of:**
- **communications**
- **ethics**
- **use of computing tools**
- **laboratory**
- **safety**

**To be addressed later:**
- **Math**
- **Physics**
- **Chemistry**
- **Biology**

* Does not include "self-evident" modules (i.e. thermo)

## Module: Dynamics and Feedback
(includes complex systems; 6 wks)

- Transient Phenomena:
  - ignition/extinction/hysteresis/oscillations/instability
- Effect of Feedback
- Complex networks
  - emergent behavior
- Analysis
  - frequency response (i.e. spectroscopic methods)
- Examples:
  - chemical reactors
  - population dynamics (virus proliferation, etc)

## Module: System and Parameter Identification
(6 weeks w/ pre-reqs)

Selection of most appropriate equations and properties within those equations to describe physical phenomena

- Choosing Model Structure
  - linear vs non-linear
  - order of system
  - first principles vs empirical

} candidates ⇨ optimization ⇨ Selecting properties/parameters | - model discrimination - model reduction

- Examples
  - kinetics
  - spectroscopy
  - transport properties
  - metabolic engineering

## Module: Interfaces
(10 wks)

- Forces
  - intra- & inter-molecular
- Adsorption
- Structure of Interfaces
- macroscopic properties
  - surface energetics: wetting, surface tension, curvature
  - mechanical properties
  - surface/volume ratio
- stabilization & self-assembly
- Examples
  - block co-polymers
  - liposomes
  - coatings & thin films
  - cell adhesion

- nanoparticles
- MEMS
- chemical and biological sensors
- catalysis

## Module: Unified Balances
(16 wks)

- Continuum
- Conservation
  - of mass
  - of momentum
- Balances
  - of mechanical energy
  - of thermal energy
- Population Balance
- Closed Systems
- Open Systems (Transport Systems)
- Moving and Inertial Systems
- Constitutive Equations
- Applications
  - they're everywhere

- cells (vs size)
- crystals

## Group D
Curriculum Presentation

Wednesday Afternoon
April 9, 2003

## What Do ChemEs Do?

- Make molecules and materials with desired functional properties
- Empowered to understand the versatility of core principles
- In the context of broader societal issues

## Systems

freshman

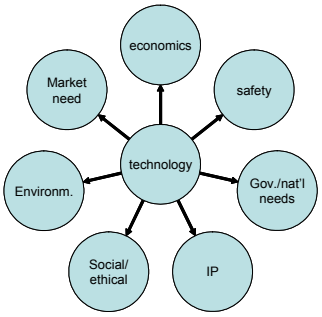
sophomore

junior

senior

Obj: Outline strategy for real-world problems

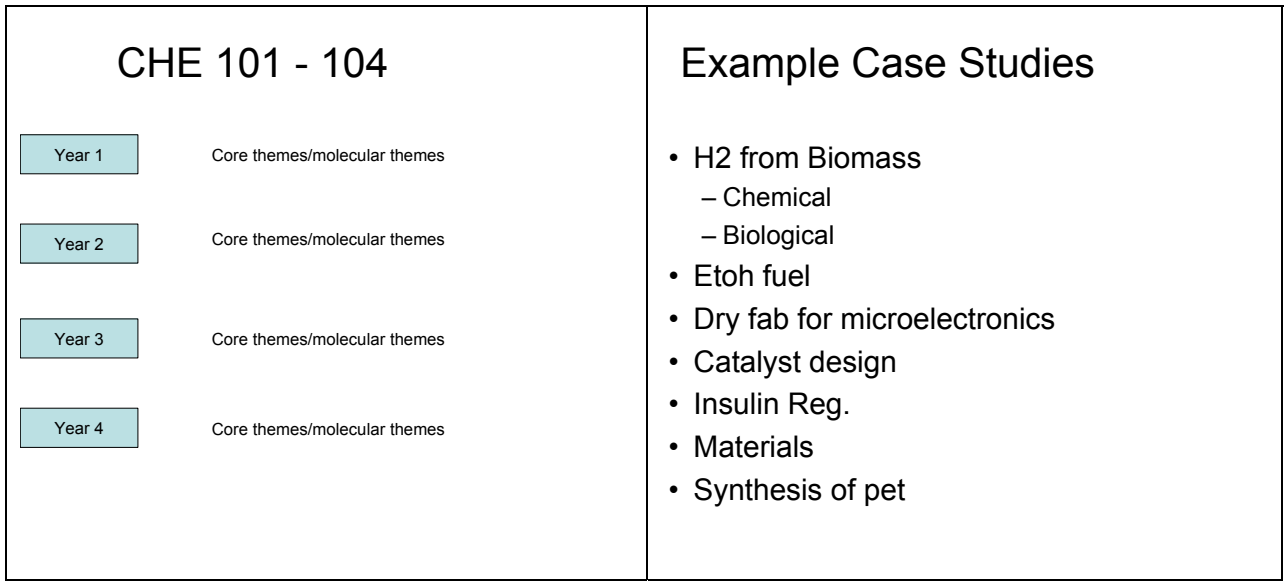
1st question: Is it worth pursuing? What are the issues?




2nd question: What are tech. issues?
•Is process…
•
•

| Systems | Fund. | Electives |
|---|---|---|
| Fresh. 1 ⟷ | Enabling | |
| Fresh. 2 ⟷ | …. | Market |
| Soph. 1 ⟷ | …. | IP |
| Soph. 2 ⟷ | Kinetics | Economics |
| Junior 1 ⟷ | …. | Etc. |
| Junior 2 ⟷ | …. | |
| Senior 1 ⟷ | …. | |
| Senior 2 ⟷ | | |

Systems & labs




**Discussion of Session 3 (Wednesday PM) Small Group Reports on Curriculum**

- Group A – Group D have the same concern:
  - What to accomplish and affirm big change
- Cannot foresee new tools, but we can be ready
- A difficult detail – what to throw out, or how to package to fit into 4 years?
- But we don't have to teach it all – work hard on core, and teach students how to learn
- Present core material as needed, motivated within a topic module
- Did we omit unit ops?
- But unit operations may be covered in distributed labs
- Importance of material balances must be remembered
- Fluid mechanics, for example, has an intrinsic structure that may not admit carving up
- However, perhaps it can be condensed < semester
- Faculty/student relationships – do we diminish acquaintance with short modules?