Reports on Questions

Question 1: What skills, attributes, and values will the ChE need in 2015?

Knowledge

- Broader spectrum of basic sciences
  - Material science is required as a full enabling science
  - Molecular biology is required
  - chemistry - organic and physical chemistry?
  - math/statistics
  - physics
- Level of coverage in a curriculum is based on Program Objectives of the individual school
- Use of software vs. understanding fundamental calculations
- Industrial input from all levels (R&D through sales/marketing)
- DO NOT WANT skills linked to type of degree program, such as multiple degree tracks in ChE, or a BS in ChE Practice
- Prefer a single degree program: a ChE curriculum that provides fundamental skills for success in all areas of practice

Skills

- Communications
  - cross-cultural; 2nd language
  - cross-technical/multidisciplinary
  - cross-educational-level
  - documentation
  - listening
- Quality Control/Six Sigma, ISO xxx (tentatively suggested)
  - statistical
  - many manufacturing/product sectors
  - supply chain/product chain management
- Management/Finance
  - organizational dynamics
  - project management
  - global issues
- Teamwork
  - leader/member
  - organizational skills
- Problem Solving
  - interpret data
  - design experiments
  - uncertainty *
  - problem definition

Attributes

- Problem Solver

- Flexible/Adaptable
- Intellectually open
- Self-confidence/efficacy
- ChE Practice
  - multiscale thinking
  - systems approach
- comfort with self-directed learning

Values
- sustainability
- ethics
- environmental, health, and safety
- commitment to profession (anchor)
- societal impact

Question 2: What will ChE careers look like in 2015? Who will be hiring?

Careers:
- Increasingly global
  - may need foreign language and cross-cultural interaction skills
  - better managerial background, because the shift toward management is occurring earlier, and more engineers go toward management
- Chemical engineers will need to make key contributions in non-traditional areas; must avoid being perceived as knob-turners
- continued increase in computer power, and computer use

Future Jobs
- In 2015, expect a substantial fraction of ChE jobs will still come from fuels and chemicals
- Licensure
  - more smaller, regional companies
  - smaller schools especially will support regional employers
  - what will be the impact of limited recruiting by companies? (recruiting limited to key schools)
  - changing jobs and areas more often
- Traditional core of employers
  - petrochemical
  - fuels/energy
  - pharmaceutical
  - environmental
  - bio-related energy
- Non-traditional employers
  - microelectronics
  - pharma → molecular engineering
  - new energy (H_2)

  - bio
  - environmental/green engineering systems
  - more consulting, broader tech/managerial expertise
- Recommendation: keep a ChE core in the curriculum and adopt tracks, or concentrations for new employment areas
- Observation: beltway politics directs research direction, which directs future growth areas

Question 3: What aspects of molecular transformations should a ChE know in 2015?

Summary:
- The ChE should be able to solve any problem!
- There are three basic groups of molecular transformations, each relying on molecules and manipulation, but the underlying cultures are divergent
  - organic chemistry (traditional ChE area)
  - materials science (semiconductors, polymers)
  - biomolecular science (Krebs cycle - a fundamentally different chemical transformation)
- The curriculum should maintain traditional problems, introduce partly-solved problems, and evolve to incorporate biological problems by (1) requiring about two new courses (2) folding bio problems into the existing curriculum.
- Computation should play a key role in curriculum

Definition of molecular transformations:
- breaking and forming bonds - organic, inorganic, biological, physical
- scale-up to useful product
- manipulating on the atomic/molecular level to influence macroscopic properties
- copolymers
- molecular design - cat + test
- drug design
- metabolic engineering
- separation agents

ChE -- polymer solid state (materials)
--synthesis, catalysis, rheology, separation, purification

Examples of Molecular Transformations in the curriculum
- cell as a reactor
- not more courses, but modify existing courses to incorporate molecular transformations
- kidney as a separator
- separations + mass transfer (including biological applications)
- biochemical engineering class
- biology 1010
- biochemistry
- numerical and computation from freshman year in different classes
- molecular approach will enhance (help) the traditional areas (applications of ChE)

- rediscover/recapture energy
- more exiting classes (atom → bulk)
- computing (junior year?) modeling and design
- lab experience
- unit ops → molecular
- molecular theory - a tool, not an end
- quantum is a must
- adjust the enabling sciences to better support the ChE curriculum

What should the student know?

- early exposure to molecular concepts, followed by consistent reinforcement
- same problems vs. new problems - problems are critical!
- how open-ended should problems be?
- computational molecular properties
- how to integrate, make consistent, reinforce - this is a challenge

Question 4: What aspects of multiscale analysis should a ChE know in 2015?

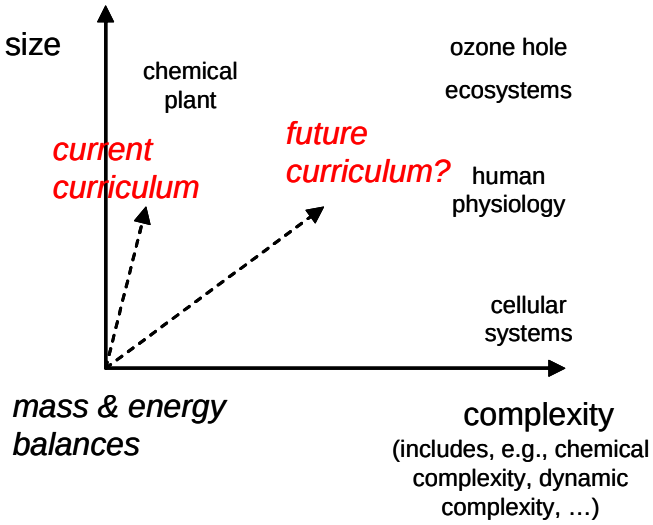
- Phenomena occur at different length (nano to global) and time scales
- Recommend a helical teaching approach
  - introduction
  - reinforcement
  - enrichment
- Interplay between
  - multiscale and systems
  - multiscale and molecular transformations
- should we have "integrated" courses or "modular" courses? Should we depart from the traditional semester schedule?
- Are we presently doing what was done in 1915? That is, introducing:
  - industrial biology
  - industrial materials science

What are the principles of the discipline?

- They remain the conservation of mass, momentum, energy, etc.
- However, there are now new dimensions to these principles:
  - complexity (biological system)
  - conformational issues, such as denaturing
  - aggregation and assembly, leading to new behavior
  - stochasticity
  - heterogeneity of function and structure

Question 5: What aspects of systems approaches should a ChE know in 2015?

View systems on axes of size and complexity:



Education in systems approaches should include:

- Sustainability
  - integrate into systems
  - social, environmental, and economic impact
- Ambiguity and uncertainty
- Examples of new products and processes that are
  - environmentally friendly
  - trend-leading and positive (e.g., drug delivery)
- A few simulators today capture much knowledge - how do we teach this? We're not using them well at present.

Tools from math	Systems activities	Example applications
• linear algebra • optimization • probability, statistics, design of experiments	• modeling • synthesis • manipulation • dynamics • mass and energy balances	• scheduling bath chemical plant • fuel cell optimization • biological reaction design

Question 6: What content would you include in the UG ChE curriculum in 2015 that would convey the excitement and novelty of your research?

The enthusiasm of research is the message to be conveyed to undergraduates

- demonstration experiments
- integration of National Science Foundation REU (Research Experiences for Undergraduates) sites - give credits for REUs
- bring undergraduates into research labs
- comparison with the CO-OP program

- changes in the Unit Ops lab
- national research competition
- that ABET thing
- capstone research programs/classes (e.g., fuel cells)
- in research we often develop “widgets” - the curriculum is missing product design
- use the themes of molecular transformations, multiscale analysis, and systems in UG research projects
- critical thinking skills are needed - that is a primary motivation for having undergraduates engage in research
- we must get the other colleges and departments (e.g., chemistry, math, physics) to cooperate with ChE in undergraduate research
- requiring faculty members’ research to be part of their teaching
- create a national database of modules for shared use