Session 2: Curriculum Topics

Workshop participants divided into five groups to address topics of curriculum content, curriculum delivery, and industrial participation. Their presentations are transcribed below. The organization of the presentations varies according to the topic and the manner in which the group approached it.

Topic 1: **Design and Synthesis.**
What kinds of things will chemical engineers design in 2020? What additional concepts need to be taught to enable these new designs, and how do we best integrate synthesis/design throughout the curriculum so these key ideas are a real focus? (Discussion leader: Richard Braatz, UIUC)

- Our foci are: BIO/ NANO/ SOLAR/ NUCLEAR/ ENVIRONMENTAL
- Themes
  - Low-value raw/waste material to high-value products
  - Designing for frontier products (2005)
  - Design emphasis at molecular level
  - Multi-discipline communication
  - Integrative modeling skills
  - Additional fundamental science
  - Project latitude/longitude – development & implementation
  - Soft skills & technical communications
  - Emphasis on enabling sciences & use in design process
- Addressing the specific questions:
  - What will we design in 2020?
    - Nanoscale products
    - Smart materials
    - Human organs
    - Conventional petrochemicals
    - Elemental recycling processes
    - New technologies for conventional petro/chemicals
    - Fuel cell power plant
    - Fusion/fission process
    - Biological feedstock processes
    - Protein processes
    - Pharmaceuticals
    - High value-added products
    - Batch processes
    - Environmental
  - What additional concepts need to be taught to enable these new designs?
    - Product design
    - Supporting sciences
    - Industry experience
    - Nano science and technology

        - Integration skills
        - Multi scale
        - Time scale
        - Creative thinking
        - Business/entrepreneurial skills
        - Economic feasibility
        - Economics
            - Financial
            - Community
        - Communications
    - How do we best integrate synthesis/design throughout the curriculum so these key ideas are a real focus?
        - Problem-based learning
        - Design projects across multiple classes
        - Nano products
        - Cross/course projects
        - Intense physics background
        - Intense chemistry background
        - Freshman/sophomore projects
        - Pinch technology – thermodynamics
        - Biotech design
        - Economics cross-course
        - Multi-media communications
        - Multi-language exposure
        - Social/political impact
        - Ethics
- Curriculum Concerns
    - Design is backloaded in the curriculum
    - Integration is backloaded in the curriculum
    - Sciences are not integrated with design
    - Fundamental data/chemistry to support projects missing
    - Existing faculty need to be re-tooled
    - How do we integrate fact knowledge & skills to produce flexible engineers (generalists)?
- Proposal
    - Progressive design projects, increasing in detail and certainty
- Next Step
    - From the SAChE/CAChE paradigm, we propose DAChE to create design/integration/synthesis projects, available to universities

Topic 2: **Learning Case Studies.**
What are some examples of case studies or characteristics/components of case studies that would enhance learning? Please illustrate by a specific case study example that you would want to see developed. (Discussion leader: Cammy Kao, Stanford)

- Existing Case Study experience:
  - "I-Pro" (Intro to Profession) Junior course at IIT (3 hours) – all engineers take this for past 7-10 years
    - Case study format (~20 ChEs, ~100 engineers)
    - Interdisciplinary teams
    - Solution – can spend $ for information acquisition
    - 2 – 3 faculty consultants (also use experts outside ChE)
    - Also use adjuncts (usually from industry)
    - Develop solution to an industrial problem (including design)
      - e.g., plastic recycling, water purification/ desalination, sustainability)
    - Problems suggested by faculty research & industry
    - Scale-up to 50 students? Resources needed?
- Possible Case Study topics:
  - Technology Development in China, India, etc.
    - Clean coal utilization
  - Sustainability (animal waste → rural energy)
  - Sustainability Case Study on Coal Utilization – problem statement
    - Coal usage in the U.S. will be greatly restricted in 2010 due to greenhouse gas problem
    - Natural gas will not be allowed in power production in 2010
    - How do we maintain current level of economic well-being without environmental degradation?
      - → Decarbonization of energy systems
- New case studies distributed each year and disseminated internationally. Professors at different universities can interact and compare results in different countries.
  - How to use energy more efficiently?
  - How to produce energy cleanly?
  - How to use energy more cleanly?
  - Without irreversible environmental damage
- A case study on energy needs: How to secure without irreversibly damaging the environment?

Short-term	Transition	Long-term
Coal (US, China) → coal gasification	Nuclear	Solar
Oil (mostly imported)	Natural gas (unconventional sources)	Wind
Natural gas	Wind	Geothermal
Nuclear (20% power production)	Tar sands (Canada)	(Fuel cells, H_2 are carriers)
Energy Efficiency		

- Relating the energy case study to the Organizing Principles

Molecular	Multi-scale	Systems
Surface chemistry	Molecules, particles, reactors	Models, simulation, optimization
Reaction rates	Transport effects	Flow-sheet selection, economics
Thermodynamics	Particle/particle interactions (growth, agglomeration, breakage)	Safety
By-products		Atmosphere, land, water, government regulations

- Relating the energy case study to skills and attributes
    - explicitly invoke skills and attributes in designing the case study
    - Social, political, economics, culture, advertising

Topic 3: **How Do We Best Learn?** and **Skills and Attributes.**
How do you best learn - as a student or when you were a student? (Text? Laboratory? Hands-on problems? Text-based problem examples? Web modules? Teaching styles? Other?)
What skills and attributes do you see as most important for the ChE in 2015? How can these be woven into the curriculum? (Discussion leader: Scott Fogler, Michigan)

- How do we best learn?
  - Worst – lectures
  - Felder learning style index
  - Organize material in nuggets/ chunks
  - Qualitative proceeds to detail
  - Exercises – critical thinking development
  - Exercises – creative thinking development
  - Squash perfectionism
  - Interesting problems/ motivating
  - Active learning
  - Learning modes: global/ sequential; visual/verbal; sensing/intuitive; active/passive
    - Take test early on to diagnose
    - Need a mix of teaching approaches to cover these modes
    - Students need to know the modes (show them)
    - Do instructors and course designs need to adapt?
  - Experiential (labs, interactive)
  - Repetition throughout curriculum
  - Writing to learn
  - Interaction with mentors
  - Interaction with classmates
  - Conflict resolution
  - Cooperative learning
  - Group/ team skills & interactions
  - Problem-based learning
  - Case studies
  - Liven it up
  - Interactive simulations
- How do they learn what we teach?
  - Simple-to-complex spiral
  - Opportunity to fail, get feedback, & retry
  - Experiential (doing)
    - Lab
    - Work with professionals
    - Simulations
    - Exercises
    - Web-based
  - Self critique & assessment
  - Reflection
  - Report on what they learned (explain)

  - Big picture view & connections to future courses
- Desired skills & attributes to be cultivated
  - Understanding of cultures
  - Business skills
  - Awareness of the world
  - Communication across audiences
  - Team skills
  - Professional skills (time management, etc.)
  - Technology skills
  - Finding information
- What are the attributes of interesting problems?
  - Diverse technology & areas
  - Relevant
  - Interaction w/ industry, etc. (outside speakers)
  - Health or environmental or policy or safety
  - Economics
  - Interesting to students & current
  - Process or product design/ synthesis
  - Connect to fundamentals is clear
  - Hands on (lab, simulator, etc.) / visits
  - Students have some control
  - Open-ended
- Pedagogical content of problem
  - Creative thinking (brainstorming, vertical thinking/ Osborn, lateral thinking/ De Bono)
  - Professional skills
    - Social skills
    - Time management
    - Stress management
    - Team functions (Chair, Recorder, etc.)
  - Critical thinking (Socratic question - 6 types)
    - Debate problems (group presentation and critique)
  - Synthesis, analysis, evaluation
  - Constant feedback
  - Mentoring & guidance
  - Qualitative & quantitative analysis
  - Estimations (back-of-the-envelope calculations)
  - Research skills & information retrieval
- How do we implement?
  - Industrial-interest problem with teams & experiments (choices)
  - Start in sophomore year with possibility of extension across years
  - Integrate into existing courses
  - Guide the process, not the result
  - <u>Case study</u>

Topic 4: **Delivery Format.**
What is a feasible or desirable path for curriculum change to incorporate problem-based learning modules throughout the curriculum? What delivery format would best serve utilization of the new curricula (web modules? text and web? other)?
(Discussion leader: Bill Olbricht, Cornell)

- A list of media, methods, and aims relevant to instruction:
  - What does classroom mean?
  - What about "Lectures"?
  - "Books" – print on paper
  - Textbooks
    - On-demand printing
  - TV
  - Web
    - Podcast
    - iPod
  - Note taking?
    - Use books
    - Use library?
  - Life-long learning
  - Techniques for
    - "classroom" facilitation
    - learning facilitation
  - "classroom" activity
  - Format ↔ Technique
  - Archival (look-up) value?
  - Physical – sensate – experience w/text
  - Thru career
  - Benefit ↔ cost
  - INTEREST
  - RELEVANCE
- Conditions at present:
  - Do students take notes in class? (have laptops)
  - Do students read printed textbooks?
  - Do students come to class?
- Conditions in the future:
  - What technology for classroom will be available?
    - What will "classroom" mean?
  - Will lectures be part of class… or will class be devoted to other activities?
  - What will be role of videoconferencing or other remote lecture/class materials?
- Observations
  - Today's text is tomorrow's reference
  - Can we learn about impact of transition to electronic materials from organizations that distribute newsletters, proposals, etc., electronically?
  - Can modules be designed to be transferable among media and to new media?

- Want a delivery format that can be modified, updated, corrected, etc., in a timely, frequent manner without burden on the author.
- In any case, a "module" will contain:
  - Science/engineering content
  - Background on technical content for instructor
  - Suggested techniques for presentation/ classroom facilitation/ learning/ classroom activities
  - Suggested assignments/ deliverables
  - Evaluation plan
- Currently there is a lot of material for students, but not much for instructors

Assessment of Instructional Media

medium	positive	negative
Textbooks	Archival value Reference One-stop shopping Easily scanned Reviewed	Flat Not interactive Static Unlinked Becoming longer Hard to change Costly
Web	Easily hyperlinked Customizable On-demand printing Easily searched Interactive with: (people, simulations, equipment) Multimedia	No skills/attributes Quality control (especially linked sources Platforms change Developmental tools change
CD/DVD/memory device	Searchable Simulations Multimedia Inexpensive to distribute Archival value	May soon be obsolete? Difficult to produce? Expensive to produce?
Personal devices (iPod, etc.)	Universality	Limited range of multimedia
Real chemical engineering learning (A/V conveying learning experience)	Use age-similar participants/learners Mentoring rather than "lecturing" Attractive to students Teach skills/attributes	Slow Production costs Difficult to change/update
Games	Interactive Holds interest Universality Virtual reality	Production costs/skills

Topic 5: **Industry/Academic Collaboration.**
How might industry and academia best work together towards the goals of the new curricula? (Discussion leader: Barry Johnston, MIT)

- Challenge: Students go to 25-50(?) different industries. How to get input, agreement, collaboration from all these varied industries?
- Need involvement and support
  - High Level (VP, P) industry representatives
  - Should be co-sponsors to the curriculum development process; not just asked for occasional input (company names attached)
  - Technical societies are a possible mechanism for this (AIChE, gov't-NSF, API, CCR, NAE, ABET, etc.)
  - Could NSF create a program that would require industrial partners?
  - Send industry a FORMAL INVITATION to participate (we need to make the BUSINESS CASE)
- Faculty need support from their own universities. (Industry will be a partner but they won't be a driver in curriculum development)
- Specific ways that industry is involved:
  - Company helps to identify core competencies
  - Company representatives (at technical/lower-management levels, nominated from higher up because of support by VP) give frequent feedback/ review during development of materials
  - Validate final product
  - Financial support:
    - Grant for course development
    - Faculty sabbatical in industry
      - Contributes to continuation/ effectiveness
  - Use alumni-faculty networks at individual university-level (advisory boards, etc.)
  - Form a society-supported clearinghouse to support/ encourage/ form these contacts
- Maintaining the Curriculum
  - Capitalize on friendships (academic/industry) formed through curriculum development phase (guest lecture from industry, senior design project ideas/support, industrial faculty sabbaticals, etc.)
  - AIChE, CCR should consider a formal mechanism for ongoing review
  - Formal feedback mechanism, from industry, on curriculum and materials, case studies, etc.
  - Feedback from industry re: desired characteristics for new graduates (ask recruiters, lower-level supervisors)
    - Recognize there will not be a consensus
- Record of discussion in the Group:
  - 50 years ago – everything better. New refinery hire is now less trained in equipment
  - Perception – curriculum has less hands-on training
  - Problem is partly breadth of application
  - Therefore focus on principles

- Conventional design, including hands-on, not enough in university
- University must lead, but also collaborate
- Will companies take academics for sabbatical leave?
- Industry doesn't know <u>how</u> to help w/r/t faculty.
    - e.g. not enough "high-level" R&D positions
- University can encourage co-ops – make more common
- Students nervous about ChE hiring prospects
- Sophs can't find internships
    - Would curriculum change help this?
- If the curriculum is static ↔ industry/university diverge
- Need template of curriculum – then individual universities can discuss with their advising boards
- Move to AIChE, API, etc. involvement – need industrial partners
- Industry biased against <u>academic</u> initiatives
- Get AIChE, etc., sponsorship
- Company <u>names</u> attached to effort
- Formal invitation to industrial leaders
- <u>VP, P level</u> – AIChE can help get their involvement and support
- Company nominate reps to help/advise on curriculum development
- Universities seek <u>alumni</u> for input
- Short-term company technical feedback during curriculum content development, as in present guest lectures
- Move <u>faster</u> than 10 years to roll out curriculum
- Faculty need to see educational <u>materials</u>
- Will industry grant ($$) to universities to release a faculty member for curriculum development?
- e.g. oil companies might be receptive, BUT need a business case
- Company must see benefit; e.g. <u>improved</u> graduates
- BP sponsors a design course at 2 universities
    - Basic cost for student travel and BP personnel time
    - (developed between an alumnus & faculty)
- Expand a program like this, if it works
- Benefit: possible hiring from more knowledge of student
- Equipment donation – mixed blessing, because faculty may not have <u>time</u> to incorporate it
- Universities-to-industry: (1) alumni (2) AIChE to connect
- CCR, AIChE formal support to make legitimate. Get the industrial commitment
- Do this first!
- Curriculum will filter down to individual university/industry contacts