Chemistry + Math ≠ Chemical Engineering

Presentation at the Centennial Celebration of Chemical Engineering at Iowa State University

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ILLINOIS INSTITUTE OF TECHNOLOGY

Outline of Discussion

- Origins of our discipline?
- Where does ChE fit within Engineering?
- How has the education of (chemical) engineers evolved?
- Future of ChE education and research?

Original Need for Chemical Engineers?

- ***Solvay process for soda ash (1860s)***

  Na_2CO_3 from NaCl and $CaCO_3$

  92×10^9 lbs/year, half used for glass

- ***Haber-Bosch process for ammonia (1913)***

  Catalysis to combine N_2 and H_2

  ½ human protein has N from this process

- ***Unit Operations***

  Academic construct to meet industrial need

100+ Years of ChE

L. E. Scriven, in *Advances in Chemical Engineering, Vol. 16* (1991)

- Term "Chemical Engineering" first used in England ≈ 1880
- 1988 – Chemical Engineering curriculum at MIT
- 1888 – ChE curriculum at Glasgow Scotland
- AIChE formed in 1908 – Committee of Six
- The "Frontiers" of Chemical Engineering:

Heavy Chemicals, Chemicals from Coal Tar, Electrochemicals

Petroleum Refining

High-Pressure & Catalytic Processes

Coatings & High-Surface Area Materials

Bio – Materials, Devices, Processes

The Committee of Six (1908)

William H. Walker

John C. Olsen
President, 1931
Secretary, 1909-1926

Richard K. Meade
Auditor, 1908-1909

Charles F. McKenna
President, 1910

Arthur D. Little
President, 1919

William M. Booth
Treasurer, 1909-1910

ChE at Iowa State University

History of the Department of Chemical Engineering at Iowa State University, Lionel K. Arnold, 1970

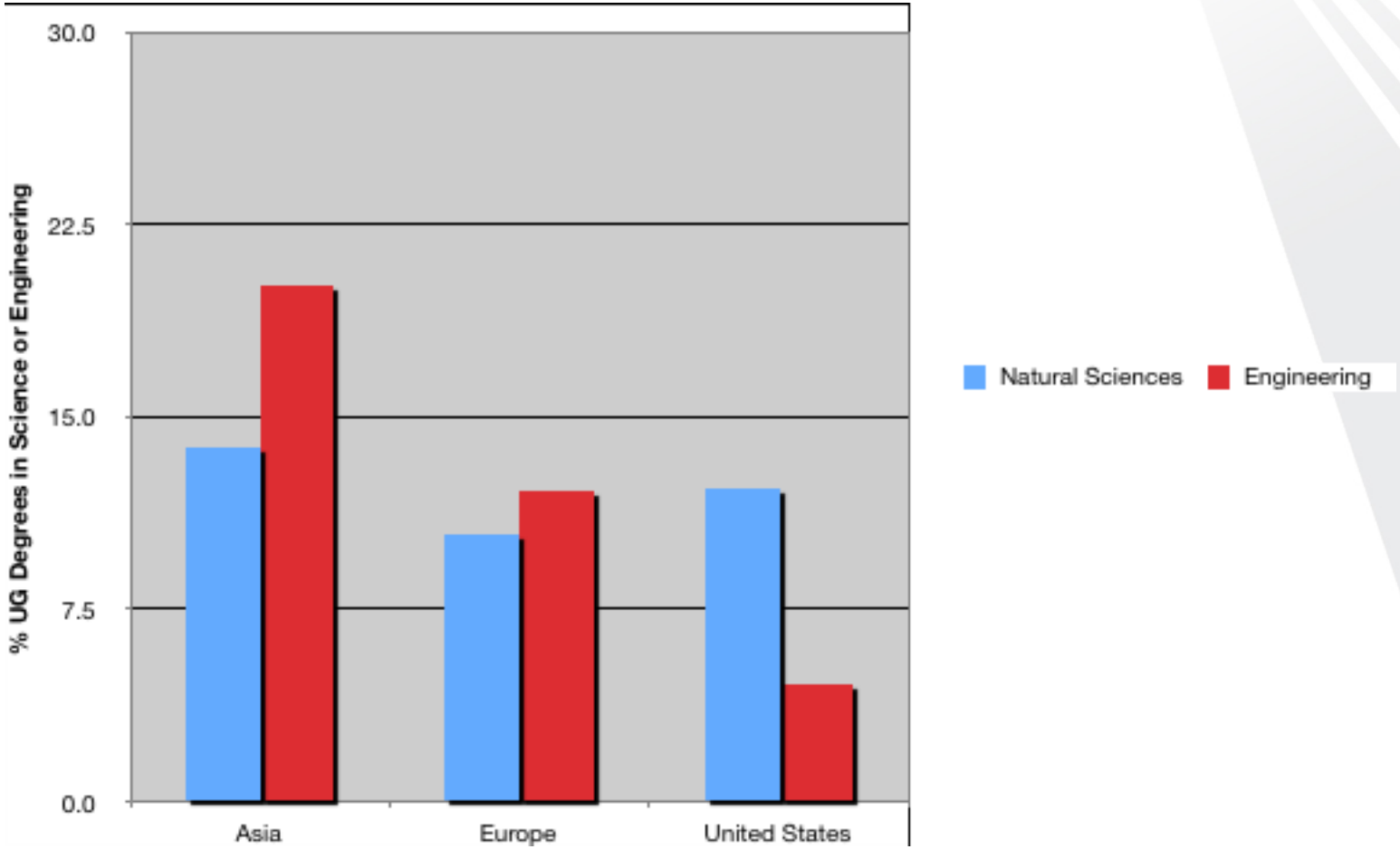
- 1862 First Morrill LG university
- 1868 – first students (agriculture and engineering)
- 1896 – Iowa State University S&T
- May 6, 1913 – curriculum in ChE established
- O. R. Sweeney 1920-47
- George Burnet, Jr. 1961-78
- Chemical and ***Biological*** Engineering

Greatest Engineering Achievements of 20th Century

1. Electrification
2. **Automobile**
3. Airplane
4. **Water Supply/Distribution**
5. Electronics
6. Radio & Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. **Air Condition/Refrigeration**
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. **Health Technologies**
17. **Petroleum/Petrochemicals**
18. Laser & Fiber Optics
19. Nuclear Technologies
20. **High-Performance Materials**

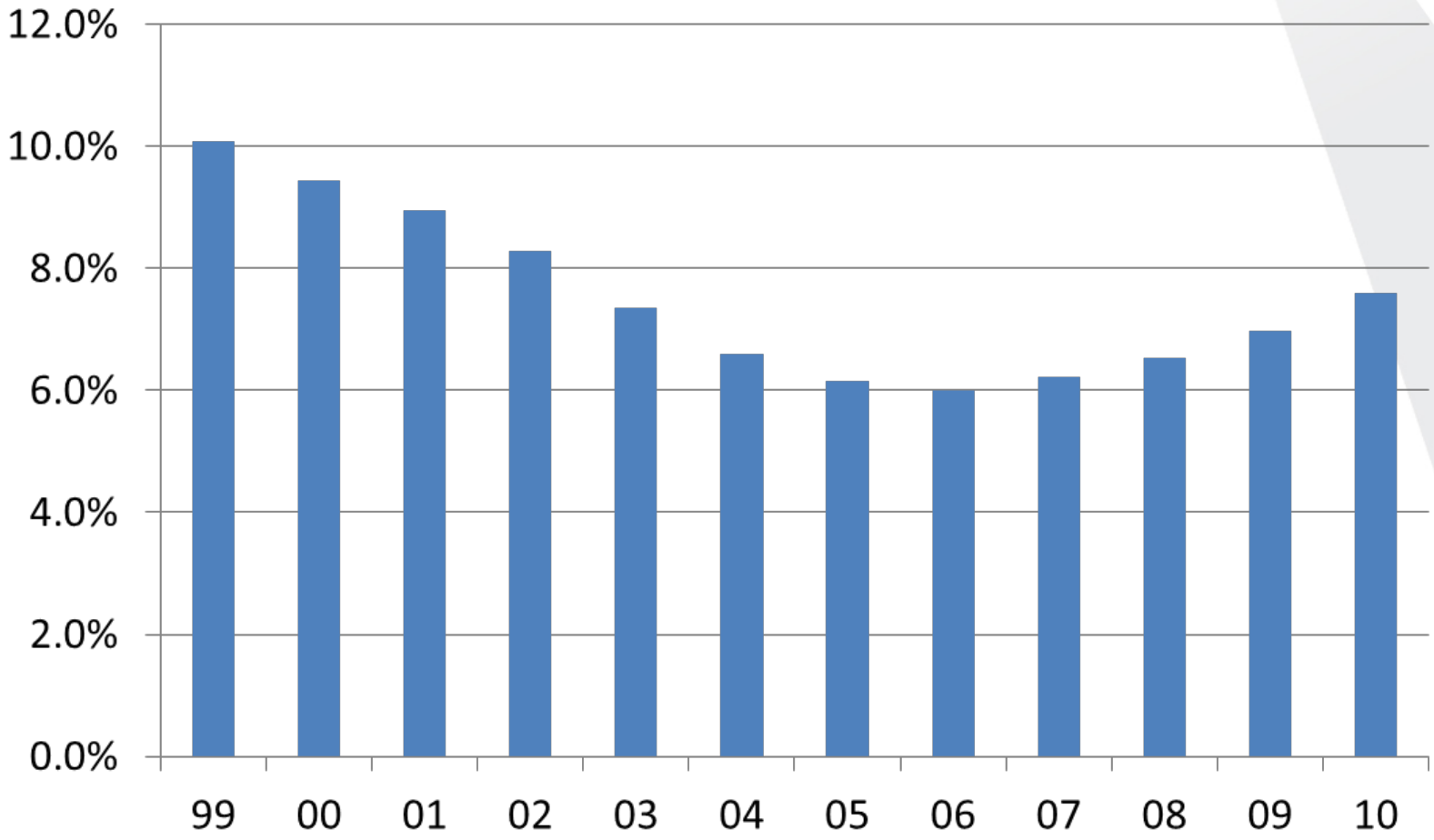
Food Safety?

Engineering is undervalued in the US



Source: NSF Science and Engineering Indicators 2008

% of BS Engr Graduates in ChE 1999 - 2010



ChE vs. Engineering

- Among smallest disciplines of engineering
  ChE: 8% B.S. degrees, MechE: 23%)
- Well paid
  (2nd highest starting salary)
- Chemistry (molecular level understanding)
- More process than product oriented

How has the Education of Chemical Engineers Evolved?

- **Core** (or, the "fundamentals")
- Niche areas – emerging technologies
- The "E" in ChemE education

AICHE Annual Mtg 1969

65th NATIONAL MEETING

TECHNICAL SESSIONS

		BALLROOM Mezzanine	CLEVELAND ROOM Lobby Floor	EMPIRE ROOM Parlor Floor	GOLD ROOM Mezzanine	LEWIS ROOM Lobby Floor	TERMINAL ROOM Parlor Floor
MONDAY	AM	1 ADVANCES IN DEVELOPMENT OF DEVICES FOR CONTROL OF AIR POLLUTION a* 9:00 d 10:30 b* 9:30 e 11:00 c 10:00	2 CHALLENGES IN MIXING VISCOUS SYSTEMS a 9:00 d 10:30 b* 9:30 e* 11:00 c 10:00 f 11:30	3 CONCEPTS AND PROBLEMS IN POLYMER SOLUTION THERMODYNAMICS a 9:00 d 10:30 b 9:30 e 11:00 c 10:00 f 11:30	4 COMMERCIAL DEVELOPMENT OF PLASTICS a 9:00 d 10:30 b 9:30 e* 11:00 c* 10:00	5 CHEMICAL ENGINEERING ASPECTS OF REACTOR COOLING SYSTEMS—WATER a 9:00 c 10:00 b* 9:30 d 10:30	6 SELECTED PAPERS—I a* 9:00 d* 10:30 b* 9:30 e* 11:00 c 10:00 f 11:30
	PM	7 ADVANCES IN AIR POLLUTION CONTROL TECHNOLOGY a 2:05 d 3:30 b* 2:30 e* 4:00 c 3:00	8 KINETICS OF POLYMERIZATION PROCESSES—I a* 2:05 d* 3:30 b* 2:35 e* 4:00 c 3:00 f* 4:25	9 VAPOR LIQUID EQUILIBRIUM a* 2:05 c 3:15 b 2:30 d 3:45 Discussion 4:15	10 GOVERNMENT POLICY ON SPACE EXPLORATION a 2:05 c 3:00 b 2:30 d 3:30	11 CHEMICAL ENGINEERING ASPECTS OF REACTOR CODING SYSTEMS—GAS a* 2:00 d* 3:30 b* 2:30 e* 4:00 c* 3:00 Discussion 4:30	12 SELECTED PAPERS—II a* 2:00 d* 3:30 b* 2:30 e* 4:00 c 3:00 f 4:30
TUESDAY	AM	13 COAGULATION TECHNIQUES FOR WASTE WATER TREATMENT a 8:45 c 9:45 b 9:15 d 10:15 Discussion 10:45	14 KINETICS OF POLYMERIZATION PROCESSES—II a* 8:25 c* 9:25 b* 8:55 d* 10:10 Discussion 10:35	15 EQUATIONS OF STATE AND THE CORRESPONDING STATES PRINCIPLES a 8:20 d* 9:45 b* 8:45 e 10:15 c 9:15 Discussion 10:45	16 EFFECTIVENESS OF PEOPLE, ORGANIZATIONS AND MANAGEMENT Panel Discussion 8:15	17 CHEMICAL ENGINEERING ASPECTS OF REACTOR COOLING SYSTEMS—LIQUID METAL a* 8:15 d* 9:45 b 8:45 e 10:15 c* 9:15	18 CHEMICAL ENGINEERING IN THE STEEL INDUSTRY a 8:45 c 9:45 b 9:15 d 10:15
		Alpha Chi Sigma Award Lecture—11:30 A.M.-12:15 P.M.—Ballroom					
	PM	19 TREATMENT OF WATER FROM POLYMER MANUFACTURE a* 2:05 d 3:30 b* 2:30 e 4:00 c 3:00 f 4:30	20 INTERFACIAL PROPERTIES OF COMPOSITE MATERIALS a 2:05 c 3:30 b* 3:00 d 4:00 Panel Discussion 4:30	21 ADVANCES IN MOLECULAR DIFFUSION—I a* 2:05 d* 3:30 b* 2:30 e 4:00 c 3:00 f 4:30	22 NATURE OF INVENTORY AND ITS MANAGEMENT a 2:10 c 3:10 b 2:40 Panel Discussion 3:50	23 CHEMICAL PROCESSING OF COAL a 2:05 c 3:00 b* 2:30 d 3:30	24 CENTRIFUGATION a* 2:00 c* 3:00 b 2:30 d* 3:30
WEDNESDAY	AM	25 CUYAHOGA CLEANUP—THE UNFOLDING STORY OF A RIVER a 9:10 c 10:20 b 9:40 d 11:20	26 ADVANCES IN MOLECULAR DIFFUSION—II a 9:00 d 10:30 b* 9:30 e 11:00 c 10:00 f 11:30	27 OPTIMIZATION OF REACTION SYSTEMS—I a 9:05 d* 11:00 b 10:00 e* 11:30 c 10:30	28 PILOT PLANT SAFETY a 9:05 d 10:25 b 9:15 e 11:00 c 9:45 f 11:15 Comments & Questions 11:30	29 SYNTHETIC FUELS FROM COAL a* 9:00 d 10:30 b* 9:30 e 11:00 c 10:00	30 SOLID PROPELLANT BINDERS—A CLASS OF ELASTOMERS—I a 9:05 c 10:00 b 9:30 d 10:30
	PM	32 LAKE ERIE SICK, DYING OR DEAD? Panel-Audience Dialogue 2:00	33 POLYMERIC FILMS a 2:00 d 3:30 b 2:30 e 4:00 c 3:00	34 OPTIMIZATION OF REACTION SYSTEMS—II a 2:05 e* 4:00 b* 2:30 f* 4:20 c* 3:00 g* 4:40 d* 3:30	35 PHOTOGRAPHY IN CHEMICAL ENGINEERING a* 2:10 d* 3:30 b* 2:30 e* 4:00 c* 3:00 f 4:30	36 UTILIZATION OF MINERAL MATTER IN COAL a* 2:05 d* 3:30 b 2:30 e 4:00 c* 3:00	37 SOLID PROPELLANT BINDERS—A CLASS OF ELASTOMERS—II a* 2:00 c 3:00 b 2:30 d 3:30

EVENTS AND TRIPS

SUNDAY
Get Acquainted Party
6:00 P.M.—Event A
Cleveland Room

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MONDAY
Lewis Research
9:15 A.M.—Trip M-1
Champagne Brunch
11:00 A.M.—Event L-1
Welcome Luncheon
12:15 P.M.—Event B
Cleveland Room
B. F. Goodrich
2:00 P.M.—Trip M-2
The Flats
6:00 P.M.—Event C

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TUESDAY
Plumbrook Reactor
8:30 A.M.—Trip T-1
Case
9:00 A.M.—Trip T-2
Tour and Lunch
10:00 A.M.—Event L-2
Firestone
12:45 P.M.—Trip T-3
Cash Bar
6:00 P.M.—Event D
Cleveland Room

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WEDNESDAY
Glascote
9:00 A.M.—Trip W-1
Technical Discussions Luncheon
12:12 P.M.—Event E
Sign up early
Whitehall Room

Board Buses Superior Avenue Entrance

WHITEHALL ROOM
Mezzanine

WEDNESDAY	AM	31 THE WIDE RANGE OF BIOCHEMICALS MATERIALS a 9:00 d 10:30 b 9:30 e 11:00 c 10:00						
	PM	38 SEPARATION PROCESSES FOR BIOLOGICAL MATERIALS European Format Introduction 2:00 Principle Discussants 2:15						

How has the Education of Chemical Engineers Evolved?

- Core (or, the "fundamentals")
- **Niche** areas – emerging technologies
- The "E" in ChemE education

Niche Areas in ChE since 1960

- Transport & Controls
- Polymers
- Membranes
- Biochemical
- Biomedical
- Colloids and Interfaces
- Computer Aided Systems
- Micro-systems (…on a chip)

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Engineering "Gen Ed"

- Design methods
- Communication, Team Building
- Business (Finance)
- Systems
- Entrepreneurship

Needs of Industry?

- “Target” industries no longer clear
- Molecular level knowledge with systems level appreciation
- New ideas from academe
- People who are innovators

Definition of "Chemical Engineering"

- AIChE 1908

"..the application of chemical principles to the arts."

- AIChE 2013

"Chemical engineering is the profession in which a knowledge of mathematics, chemistry, and other natural sciences gained by study, experience, and practice is applied with judgment to develop economic ways of using materials and energy for the benefit of mankind."

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- Robert Pigford

"Chemical engineering is what chemical engineers do."

Future?

"Life can only be understood backwards, but it must be lived forwards."

- Søren Kierkegaard (1813-55)

"Never, ever, think outside the box."

L. E "Skip" Scriven, "Perspectives in Chemical Engineering", *Advances in Chemical Engineering*, Vol. 16 (1991)

In brief, the practice of chemical engineering, like seasonal foliage, changes; like individuals, the sub-disciplines grow, mature, and give birth to others; the discipline like a species evolves, but the **essence, like a tree, is invariant**. For the better part of a century, the profession in the United States has **broadened its base** - now rejoining materials science - and built on it successfully to fulfill the needs of both the existing and the **emerging** chemical process technologies of each era. As past high technologies have matured, and turned senescent or moribund, the profession has again and again moved on to new frontiers, rapidly enough to avoid any danger of extinction. What factors are likely to be important for the next hundred years? Primarily those that have been important over the past hundred. My encounters with them leave me with two deep questions that remain largely unanswered. **What constitutes an engineering discipline like chemical engineering? And what maintains the associated profession?**

The Future of ChE Education?

- Wickenden Committee, ASEE (1927)
- Doherty, R.E., "The Development of Professional Education", Carnegie Press (1950) – the "Carnegie Plan"
- **Grinter, L. E., "Report on the evaluation of engineering education", *J. Engineering Education* (1956)**
- Lundgreen, P., "Engineering Education in Europe and the USA, 1750-1930", *Annals of Science* **47**, 33-75 (1990)
- National Academy of Engineering, "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" (2005)
- **Seely, B. F., "Patterns in the History of Engineering Education Reform: A Brief Essay" in *Educating the Engineer of* 2020, National Academies Press (2005)**

The Future of ChE Education?

- Products, not just processes
- Emphasis on creativity in addition to analysis
- Multidisciplinary projects
- Re-think graduate education

The Future of ChE Research?

- *Frontiers in Chemical Engineering Research: Needs and Opportunites* (Amundsen Report 1988), NRC
- *Beyond the Molecular Frontier*, NRC (2003)
- *International Benchmarking of US Chemical Engineering Research Competitiveness*, NRC (2007)
- *Arise 2: Unleashing America's Research and Innovation Enterprise,* American Academy of Arts & Sciences (2013)

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The future is decided by the young.

Final Thoughts

- "Chemical Engineering" should <u>not be limited</u> by what chemical engineering majors study.
- Education should be guided by needs of industry, but research should be guided by researchers.
- "Gen Ed" needs to be re-thought.
- Future research themes will be determined by the young, and innovation will go from university ➔ industry.

Final Thoughts +

- "Chemical Engineering" should not be limited by what chemical engineering majors study.
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- "Gen Ed" needs to be re-thought.
- Future research themes will be determined by the young.

"Scientists study the world as it is, engineers create the world that never has been." **- Theodore von Karman**

The End