

Introductory lecture

An Engineers Toolchest

useful tools for engineers in the real world

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Engineer's Toolchest Course
University of Washington
Bioengineering 599

Spring, 2003

Why do we need an Engineer's Toolbox Course?

- Most engineers never formally receive this type of material
- An engineer's job performance affects other people (often millions)
 - an engineer must take responsibility for his/her actions
- We live today in a complex, contentious workplace

Litigious

regulatory (ISO, OSHA, etc)

big business

Political

new technologies

the public perception of science and technology is negative

There is confusion between academic engineering and “real world” engineering – What is science? What is engineering?

It is one thing to solve a differential equation and another to successfully cope with the conflicting demands of the modern workplace.

Mostly,

We want to graduate you so you're
feeling like an engineer!

Lectures -- Spring, 2003

- Apr 2 Introduction to the course and the Philosophy of Engineering – Buddy Ratner
Effective communications (oral) – Buddy Ratner
- Apr 4 (Eng. design)
- Apr 9 Good Notebooks, Patents, Project management (A. Branca)
- Apr 11 (Eng. design)
- Apr 16 Effective Communications class exercises (Ratner)
- Apr 18 (Eng. design)
- Apr 23 Technical Writing - C. Plumb / Creativity (B. Ratner)
- Apr 25 (Eng. design)
- Apr 30 IP and Ventures
- May 2 (Eng. design)
- May 7 Access to Information (Mel Desart) / legal issues affecting engineers
- May 9 (Eng. design)
- May 14 Public perception of technology (Illman) / Creative Problem Solving – B. Ratner
- May 16 (Eng. design)
- May 21 Entrepreneurship - the industry perspective (Chris Somogyi)
Entrepreneurship - the university perspective – Prof. Yongmin Kim
- May 23 (Eng. Design)
- May 28 Ethics I & II- Buddy Ratner
- May 30 (Eng. Design)
- June 4 Diversity in Science and Engineering / BioE Assessment
- June 6 (Eng. Design)

A History of Engineering

(Latin root: *ingeniare* – to design or devise)

10,000-3000B.C. spear thrower, the wheel, plow (and yoke), looms

4000-3000B.C. metallurgy

3000B.C. the great pyramids of Egypt

2100B.C. The Code of Hammurabi (Babylon) defines legal penalties for faulty construction

300B.C. The first science – Euclid / Archimedes

1196 the term “encignierius” used in Lombardy

1100+ the great cathedrals of Europe

1300 the mechanical clock

1683 Galileo (mechanics of materials / dynamics)

~1700 calculus (Leibnitz, Newton)

1747 The start of modern civil engineering? (founding in France of École des Pont et Chaussées)

The start of modern mining and metallurgical engineering?

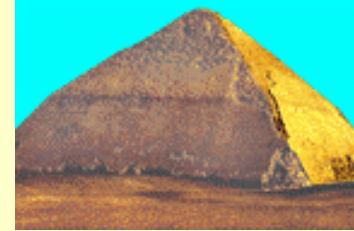
(publication of *De Re Metallica* by Agricola)

The start of modern mechanical engineering? The steam Engine – James Watt

The start of modern electrical engineering? The lightning rod – Ben Franklin

1790 The start of modern chemical engineering? LeBlanc process to make sodium carbonate

Engineering Fiascos



Egyptian pyramids (Dahshur – the “bent” pyramid)

Cathedrals in Europe (the 1284 collapse at Beauvais)

Collapse of an iron 157 foot truss bridge in Ashtubula, Ohio (1928) (100 killed)

Titanic (1912)

St. Francis dam in California bursts (1928) (400 killed)

Tacoma Narrows Bridge (1940)

DC-10 crash – Chicago (1979)

Kansas City Hyatt Regency skywalk disaster (1981) (114 people killed)

The Challenger explosion -- “o” ring failure (1986)

Failure in a strut of the heart valve in Barney Clark

The mechanical integrity of the breast implant bag? (1960’s - today)

Columbia space shuttle disaster (2003)

Rock-a-bye baby

London Bridge is falling down

Humpty Dumpty sat on a wall

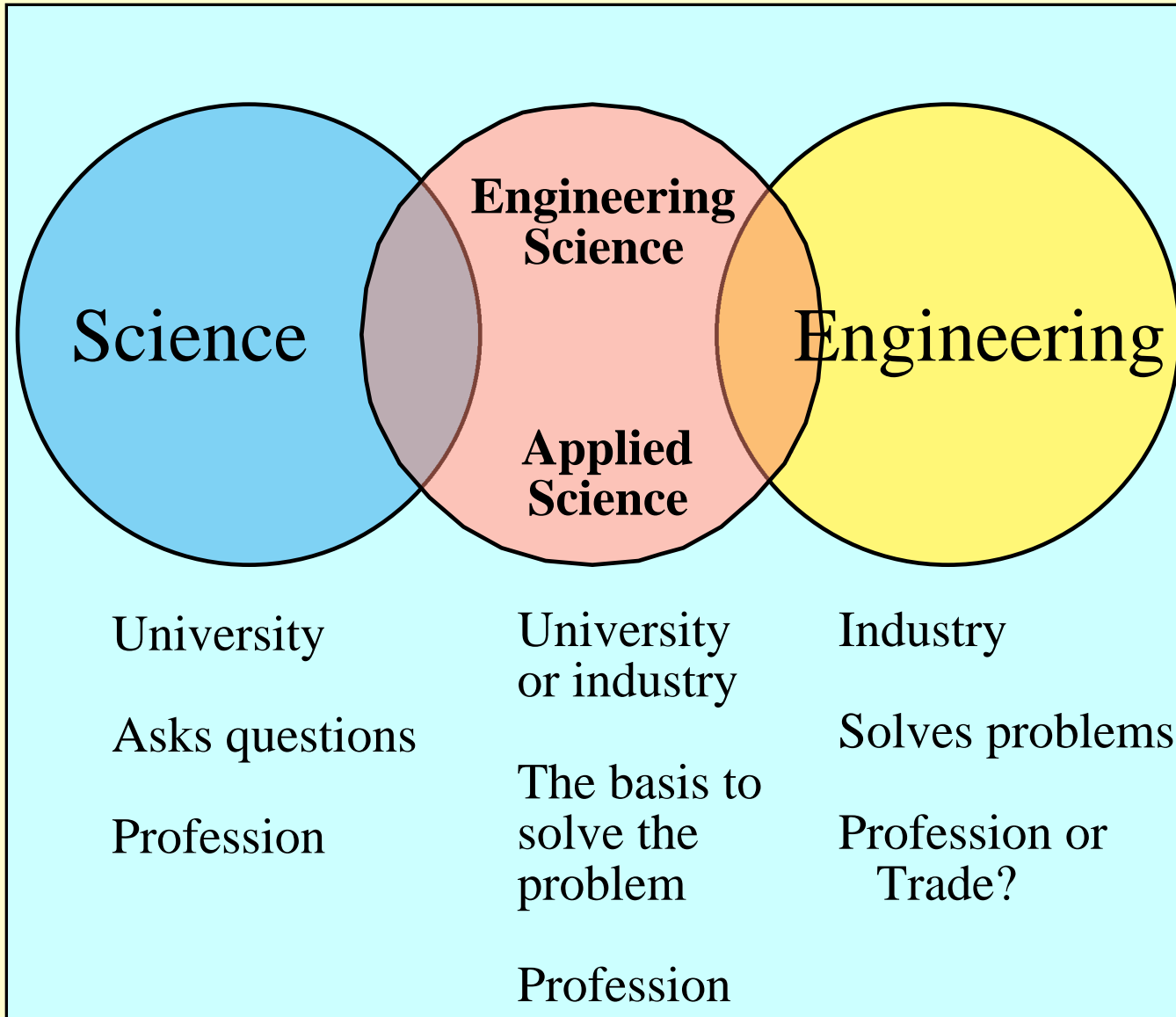
Jack and Jill went up the hill

The failures of
engineers in the
legends of the people

Interestingly (and sadly),

engineers learn from disasters

Failure analysis



What characterizes **research**? (done by both engineers and scientists)

A process of thinking.

The Phases of Research

The idea generating phase (curiosity / creativity)

Problem definition phase – the hypothesis

Procedure design phase – statistical design to acquire meaningful numbers; test the hypothesis

Observation phase

Data-analysis phase

Interpretation phase (do your results support the hypothesis?)
(a new hypothesis?)

Construct a model

Test the model

Communication phase (an oral or written report summing up the above)

Statistics are integral

The Scientific Process

What characterizes science?

curiosity (disciplined curiosity) (active curiosity)

“a discovery is an accident meeting a prepared mind” -- A. Szent-Gyorgi

asking questions (a process of inquiry)

- hypothesis is a method of questioning

knowing how to ask questions (the logic of asking questions)

skepticism

systematic acquisition of knowledge

- tenacity / intuition / authority (make few demands on the source of knowledge)
- rationalism (reason alone)
- empiricism (personal observation)

-science (combines interplay of rationalism and empiricism)

Scientific explanation must be subject to testing – thus, it is always possible it will be proven false. An explanation not subject to possible rejection is not scientific.

We must try, with the greatest enthusiasm and honesty, to disprove our favorite hypotheses

The Hallmarks of an Engineer

(ingenious contriver of the instruments of civilization – S. Hollister)

Quantitative

Dimensionless numbers

A modeling approach

Systems approach

“Borrows” from science

Rests on a technological base (there are 100,000 different journals!)

Fills a need

Problem solver (an iterative approach?)

Profit motive

Economic analysis

Creative

Inventive

An Engineer’s work is project (and project team) driven

The engineering cycle

A clear and effective communicator

Ethical (professional / responsible)

A pastor, a doctor and an engineer were waiting one morning for a particularly slow group of golfers.

Engineer: What's with these guys? We must have been waiting for 15 minutes!

Doctor: I don't know, but I've never seen such ineptitude!

Pastor: Hey, here comes the greenskeeper. Let's have a word with him.

Hi George. Say, what's with that group ahead of us?

They're rather slow, aren't they?

George: Oh, yes, that's a group of blind firefighters. They lost their sight saving our clubhouse from a fire last year, so we always let them play for free anytime.

The group was silent for a moment.

Pastor: That's so sad. I think I will say a special prayer for them, tonight.

Doctor: Good idea. And I'm going to contact my ophthalmologist buddy and see if there's anything he can do for them.

Engineer: Why can't these guys play at night?

Creative problem solving

Sherlock Holmes and Dr. Watson go on a camping trip, set up their tent, and fall asleep. Some hours later, Holmes wakes his faithful friend.

"Watson, look up at the sky and tell me what you see."

Watson replies, "I see millions of stars."

"What does that tell you?"

Watson ponders for a minute. "Astronomically speaking, it tells me that there are millions of galaxies and potentially billions of planets.

Astrologically, it tells me that Saturn is in Leo. Timewise, it appears to be approximately a quarter past three. Theologically, it's evident the Lord is all powerful and we are small and insignificant. Meteorologically, it seems we will have a beautiful day tomorrow. What does it tell you?"

Holmes is silent for a moment, then speaks.

"Watson, you idiot, someone has stolen our tent."

Observant, practical

How an engineer works:

The engineering cycle

Conceive

Experiment

Design

Make

Test

Optimize

A few more “engineers” things

Engineering is the art of directing the great sources of power in nature for the use and convenience of man

Thomas Tredgold, 1828

Rules of thumb

Think on your feet

Engineers enter engineering through science

Not afforded the luxury of “perfection.” -- Make something good enough to ship out the door.

Nerd (not necessarily)

Example: Weertman’s Rule

A metal is ductile if the ratio of the theoretical maximum tensile strength to the theoretical maximum shear stress is greater than 7

Approximate / rule of thumb / can't wait for perfection

In the high school gym, all the girls in the class were lined up against one wall, and all the boys against the opposite wall.

Then, every ten seconds, they walked toward each other until they were half the previous distance apart.

A mathematician, a physicist, and an engineer were asked,

"When will the girls and boys meet?"

The mathematician said: "Never."

The physicist said: "In an infinite amount of time."

The engineer said: "Well... in about two minutes, they'll be close enough for all practical purposes."

New engineering ideas -- how do they fit?

traditional

Modeling

Engineering

Assembly

Macrostructures

New ideas

Molecular Modeling

Protein Engineering
Genetic Engineering
Tissue Engineering

Self Assembly
Supramolecular assembly

Nanostructures

Biography on the Engineering Profession and The Research Process

H. Petroski, "To Engineer is Human" St. Martin's Press, NY, 1985

M.D. Burghardt, "Introduction to the Engineering Profession"
HarperCollins, NY, 1995

M. Davis, "Thinking Like an Engineer: Studies in the Ethics of a Profession"
Oxford University Press, NY 1998

S.C. Hollister, "Engineer" MacMillian Co. NY, 1966

D.G. Johnson "Ethical Issues in Engineering" Prentice Hall, Englewood Cliffs, NJ, 1991

L.J. Kamm "Successful Engineering" McGraw-Hill, NY, 1989

J.D. Kemper "The Engineer and His Profession" Holt, Reinhart and Winston, NY, 1967

M.W. Martin and R. Schinzinger "Ethics in Engineering" McGraw-Hill, NY, 1983

S.C. Florman "The Existential Pleasures of Engineering" St. Martins Press, NY, 1976

S.C. Florman "the Civilized Engineer" St. martins press, NY, 1987

A.M. Graziano and M.L. Raulin "Research Methods:
A Process of Inquiry" Harper Collins, NY 1989

"On Being A Scientist: Responsible Conduct In Research," Second Edition,
Committee On Science, Engineering, And Public Policy, National Academy Of Sciences,
National Academy Press, Washington, D.C. 1995

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M. Shermer "Why People Believe Weird Things: Pseudoscience, Superstition
and other Confusions of our Time," W.H. Freeman and Co., NY 1997