INCORPORATING "ENGINEERING" THINKING INTO TRADITIONAL MATH AND SCIENCE CURRICULUM

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LaSalle Academy

Providence Ri


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BACKGROUND AND PERSPECTIVE

- **B.S. Metallurgical Engineering Columbia University.**
- **Master's degree Columbia University School of International and Public Affairs. Concentration in World Resources and Technology Transfer.**
- **Product and market development experience in the steel, copper and precious metal industries.**
- **Private high school teacher for the past 13 years. Experience teaching math and introductory science. Currently teaching AP Physics (B and C) and an introductory Engineering course.**

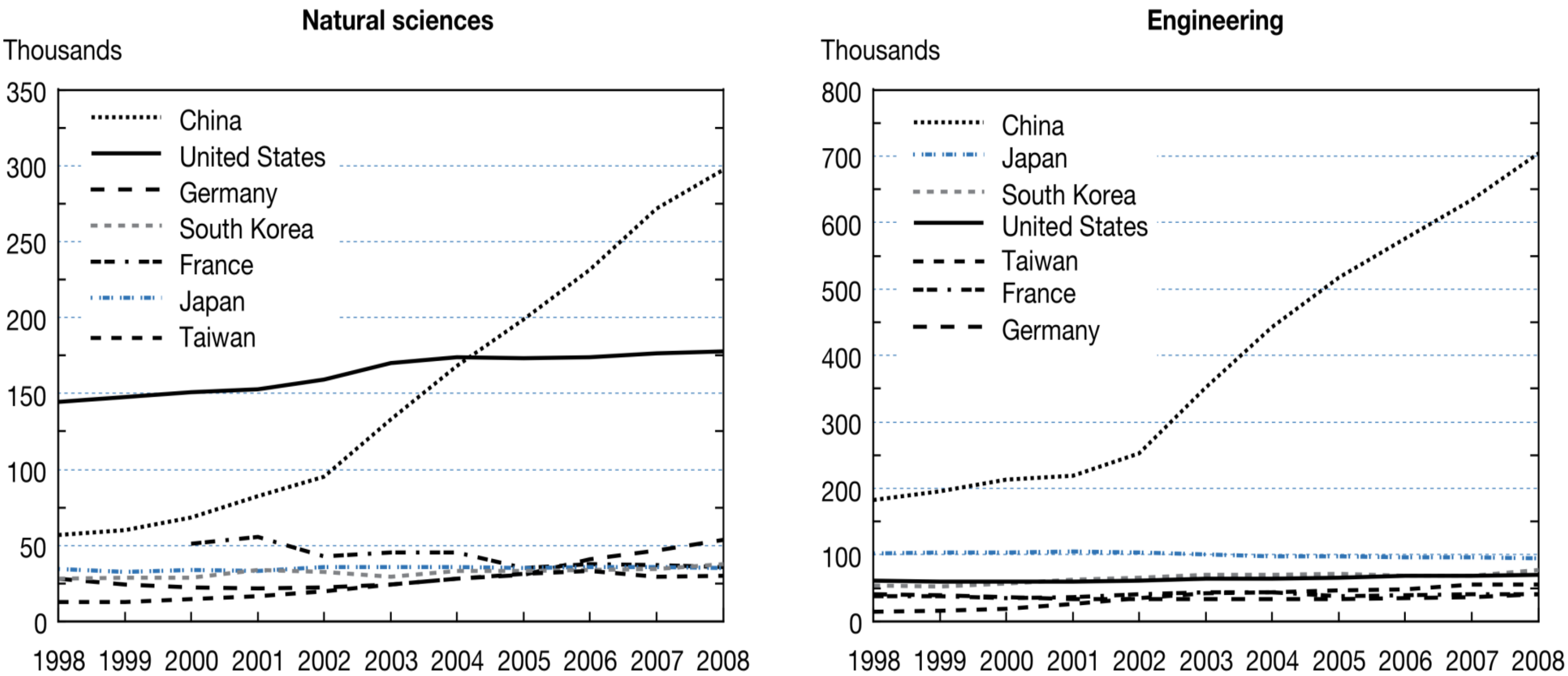
NAE: Changing the Conversation

- If young people do not know much about engineering or have a skewed view of what it means to be an engineer, we cannot expect them to seriously consider engineering as a career.

- The ability to attract creative young minds to engineering is directly tied to the nation's innovation capacity, which many experts believe is in decline.

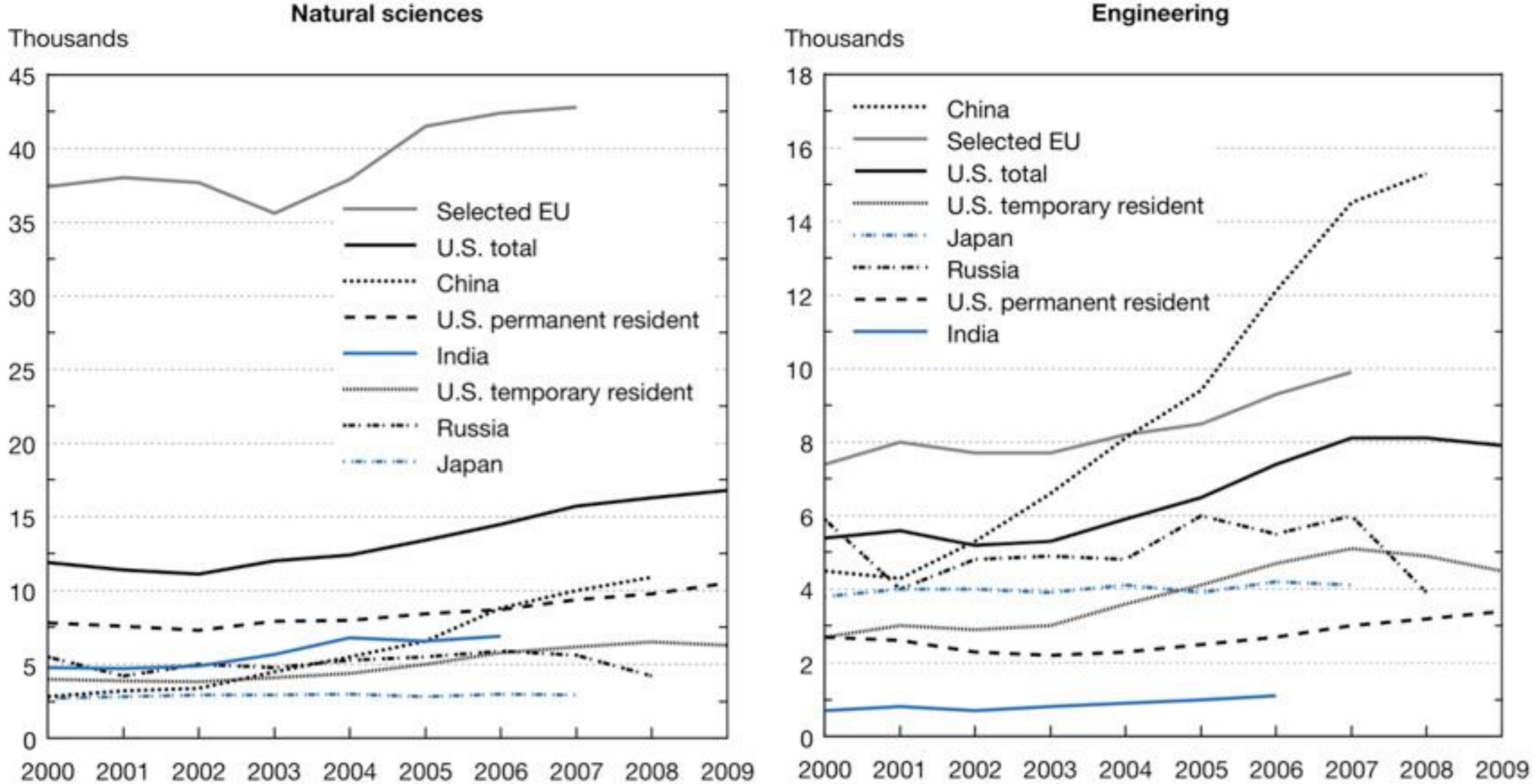
- Knowing something about how the human-designed world has been created—and by whom—is a cornerstone of technological literacy, an important attribute for life in the 21st century.

First university degrees in natural sciences and engineering, by selected country/economy: 1998–2008



NOTE: Natural sciences include physical, biological, environmental, agricultural, and computer sciences, and mathematics.

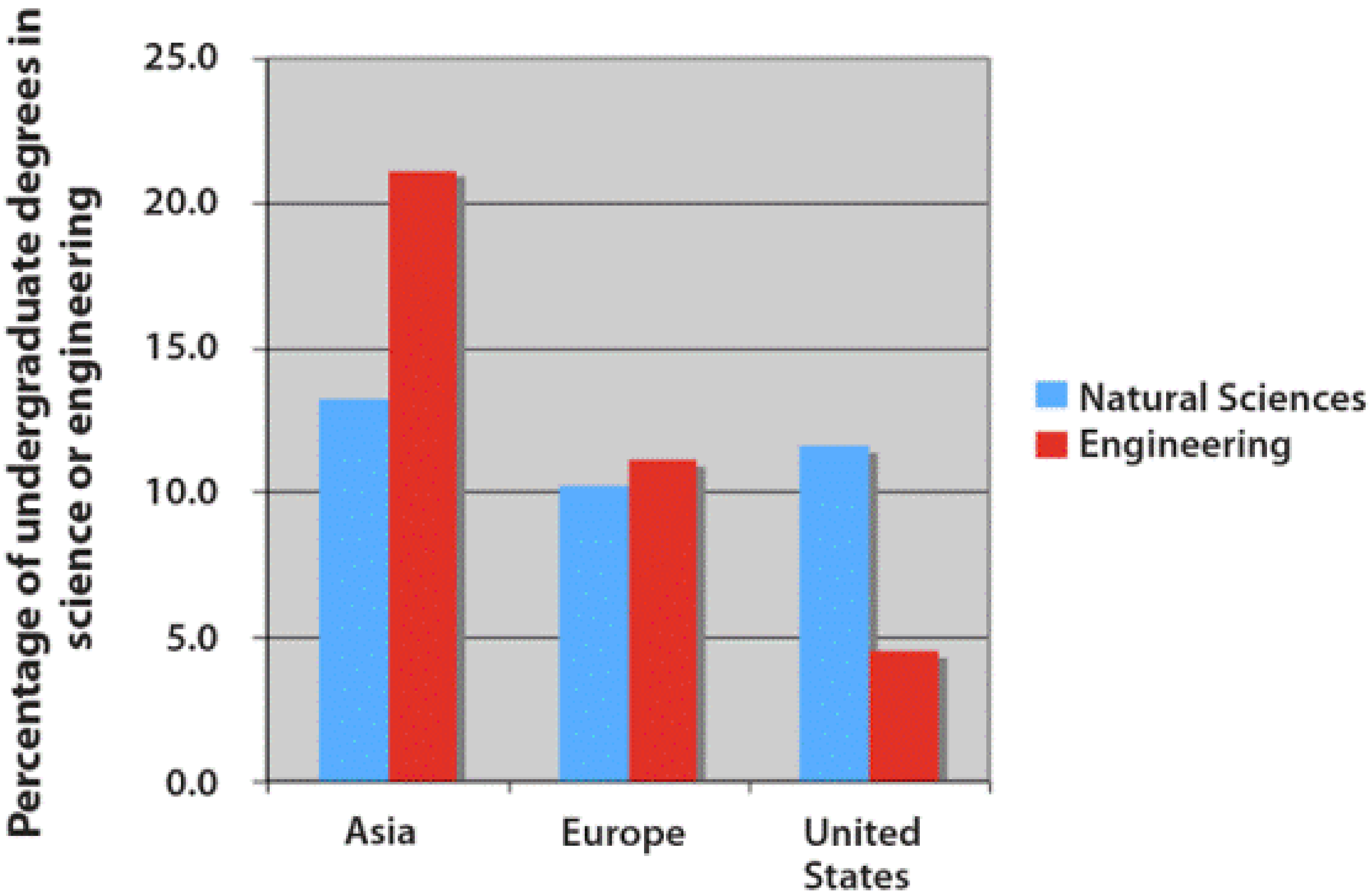
Doctoral degrees in natural sciences and engineering, by selected region/country: 2000 to most recent year



EU = European Union

NOTE: Natural sciences include physical, biological, environmental, agricultural, and computer sciences, and mathematics.

SOURCE: National Science Board, *Science and Engineering Indicators 2012*


Percentage of undergraduate degrees in science or engineering
25.0
20.0
15.0
10.0
5.0
0.0
Asia
Europe
United States
Natural Sciences
Engineering

Science vs. Engineering

- **Scientists deal with the world that is, while engineers envision the world that could be.**

- **It is the job of the engineer to determine what people need or want and figure out the best way to provide it. Engineers put knowledge into practice.**

- **Modern humans interact with two worlds at once. The first is the natural world— the components exist independently of human intervention. The second is the human-made world—all the things people have created for themselves in order to change and improve their lives.**

Without engineers, this human-made world could not exist.

Positioning Statement for Engineering NAE

- **No profession unleashes the spirit of innovation like engineering.**
- **From research to real-world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways.**
- **Few professions turn so many ideas into so many realities.**
- **Few have such a direct and positive effect on people’s everyday lives.**
- **We are counting on engineers and their imaginations to help us meet the needs of the 21st century. But, in most schools, the E in STEM is an afterthought**

My Experience Science vs Engineering

- **Students often have little recall of any learning that involved rote memorization or problem solving.**
- **Many students complain that science has not been any “fun’ since elementary school. Many traditional science classes do not encourage exploration and creativity.**
- **Students are often intimidated by open ended activities – life’s problems do not come with instructions !!**
- **Most students cannot speak the language of math and see little need for it beyond math class. Technological literacy requires a vocabulary !!**

Why Engineering ?

- Engineering has been called “design under constraint”. Every potential answer an engineer devises for a problem must be weighed against the realities of the physical world and other concerns.
- There is never just one way to solve an engineering design challenge; there is no single, “right” answer to a problem.
- Engineering requires a sense of vision that goes beyond concepts to “see” a solution that others might miss or dismiss as farfetched.
- The modern engineer must be able to synthesize a broad range of disciplinary knowledge while keeping the essential nature of the problem within her view.

ENGINEERING IS ACTIVE LEARNING!

WHY ENGINEERING BEFORE COLLEGE ?

- Students are exposed to an area that many know nothing about.
- High school students are very social and welcome opportunities to work together.
- Students who lack confidence in their scientific and mathematical abilities gain confidence as valued contributors in a group.
- Students who are bored by rote problem solving and structured labs are the very students we can least afford to lose.
- It gives students the freedom to experiment with ideas and solutions; fosters tolerance and creativity.

DO WE EDUCATE TO INNOVATE?

- Can students use what they have learned to develop solutions?
- Do students see connections or are they continually dealing with “new” information?
- Are they big picture, systems thinkers?
- Are they willing to fail?
- Do they learn from their “mistakes”?

BLOOM'S TAXONOMY

Stresses 12 habits of mind that we should seek to develop in our students. These are often called the basis for expert-like behavior in science.

1. seek alternative representations

2. generate multiple solutions

3. compare and contrast

4. categorize and classify

5. explain, describe, and depict

6. discuss, summarize, and model

7. predict and observe

8. plan, justify, and strategize

9. extend the context

10. reflect and evaluate

11. monitor and refine

12. communicate

SCIENCE

- Ask a Question
- Do Background Research
- Construct a Hypothesis
- Test Your Hypothesis by Doing an Experiment
- Analyze Your Data and Draw a Conclusion
- Communicate Your Results

ENGINEERING

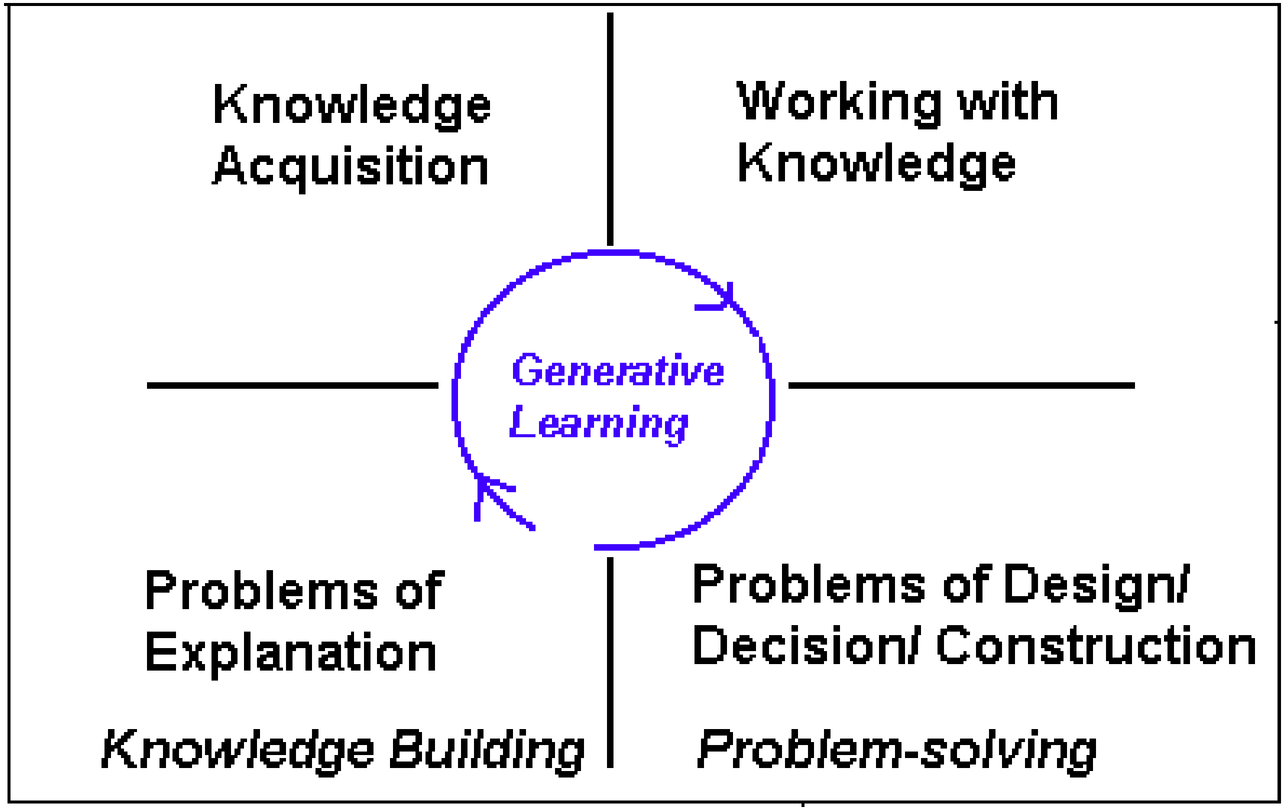
- Define the Problem
- Do Background Research
- Develop Criteria
- Create Alternative Solutions
- Choose the Best Solution
- Do Development Work
- Build a Prototype
- Test and Redesign
- Communicate

- **Engineering is action – learning by doing conveys ownership.**
- **Engineering has societal value – students can be empowered to can change the world.**
- **Engineering innovation ignores "the box" - students with different viewpoints, different talents, and different ideas can all contribute.**

Getting students excited about engineering answers
"The what am I going to do with this ?" question.

Getting students excited about inquiry, modeling and problem solving at an early age instills skills far beyond acquiring information.

It empowers them to develop their own knowledge.



- **Generative learning is about owning information by engaging it in a way that makes it relevant to you.**

- **Most traditional approaches focus on knowledge building. Engineering is problem solving!**

So What's the Problem?

- **Engineers don't teach and teachers are not engineers.**
- **Science and math teachers have their hands full covering required curriculum, which often emphasizes quantity over quality.**
- **We risk losing an entire generation of innovators if we don't encourage creativity and mastery through application.**
- **We can't teach them everything but we can teach them to think!**

The 14 Grand Challenges of Engineering are as follows:

- **Make solar energy economical**
- **Provide energy from fusion**
- **Develop carbon sequestration methods**
- **Manage the nitrogen cycle**
- **Provide access to clean water**
- **Restore and improve urban infrastructure**
- **Advance health informatics**
- **Engineer better medicines**
- **Reverse-engineer the brain**
- **Prevent nuclear terror**
- **Secure cyberspace**
- **Enhance virtual reality**
- **Advance personalized learning**
- **Engineer the tools of scientific discovery**

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- All of these challenges involve multiple disciplines.

- Health, the environment, energy, infrastructure, water needs and other future issues can all be introduced in chemistry, biology, physics and math classes.

“Engineering “ a Lesson

- **Students like tangibles – start with a real product, project or process.**
- **Determine whether students will recreate, modify or improve the product or process.**
- **Introduce or review the science behind the product.**
- **Engineering teams**

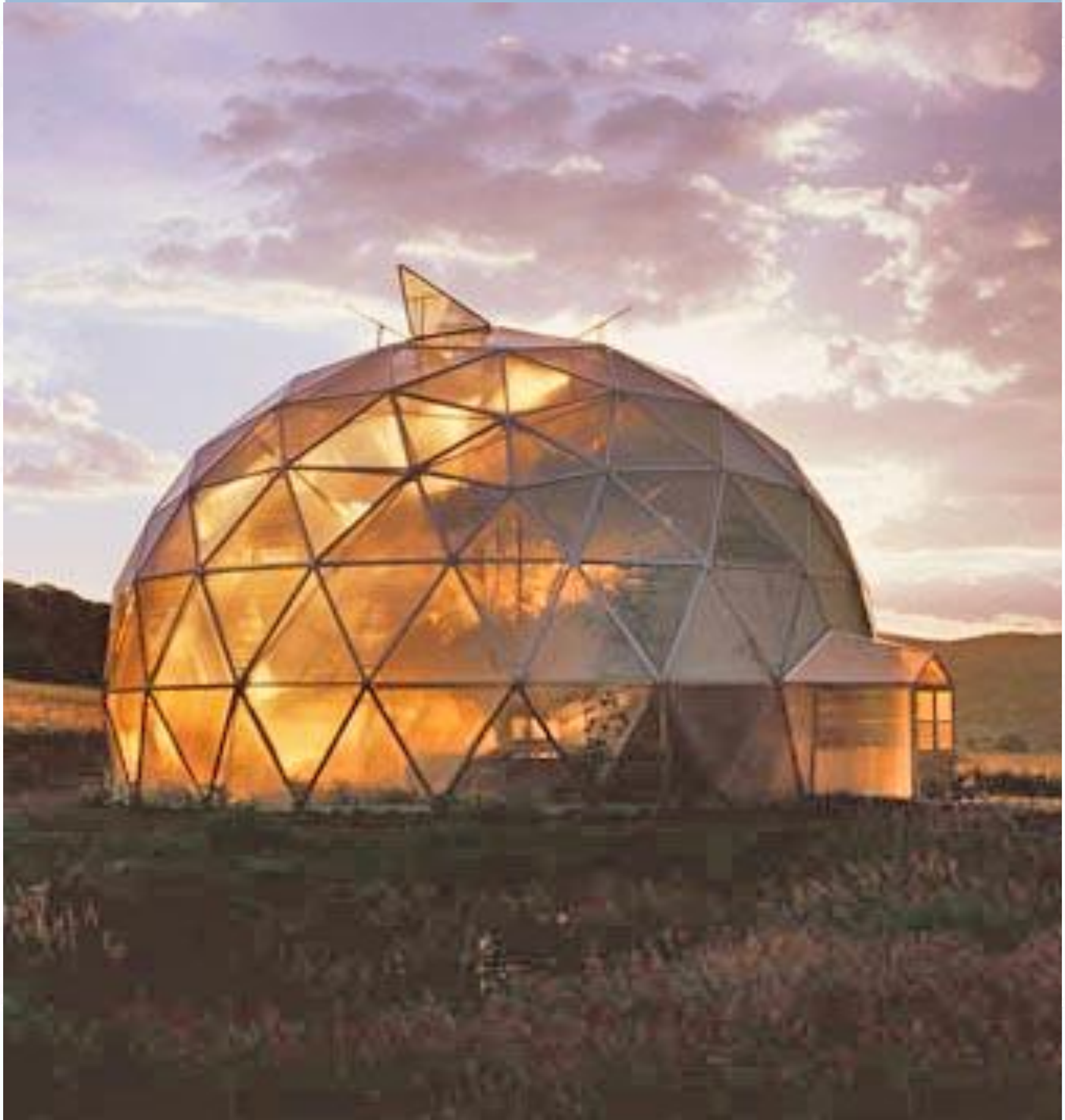
ENGINEERING “LAB”

Stress the Engineering Design Process

- **Define the Problem**
- **Research needs, approaches, problems**
- **Determine constraints and design criteria**
- **Choose a solution(s)**
- **Prototype or model**
- **Refine, revise**
- **Communicate**

Engineering Activities in Math Class

- Population issues
- GPS/ Navigation
- Traffic simulations
- Mathematical Modeling- issues such as the spread of disease, fisheries,etc.
- Crystallography
- Architecture

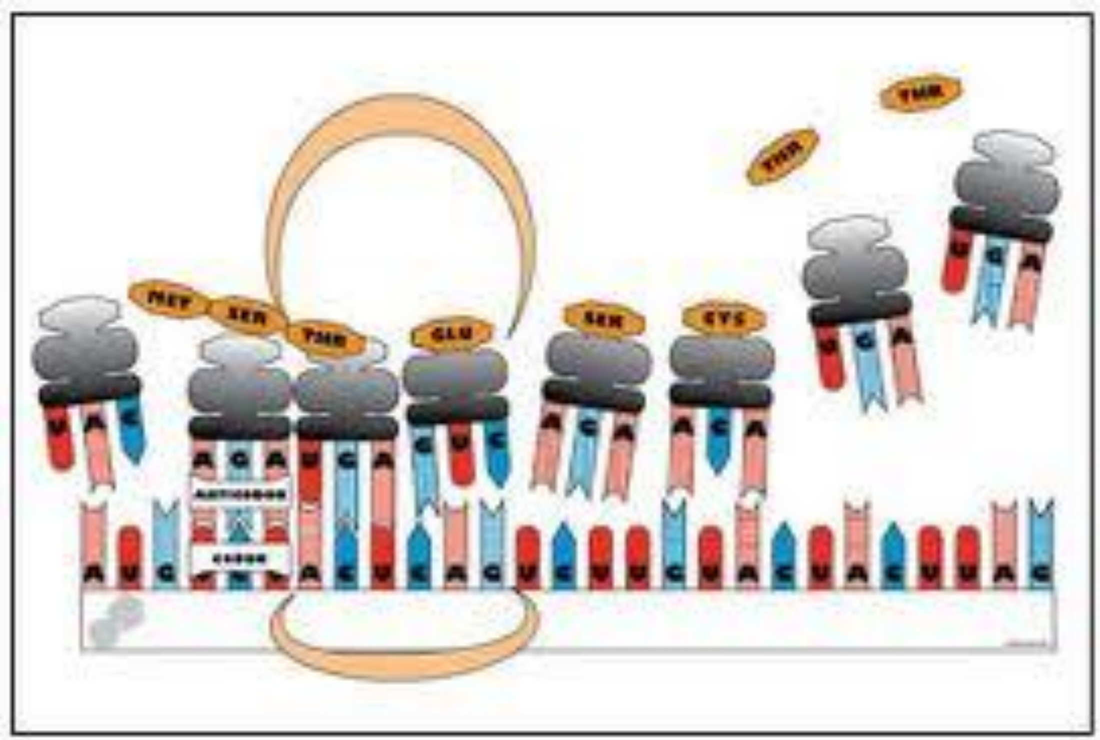


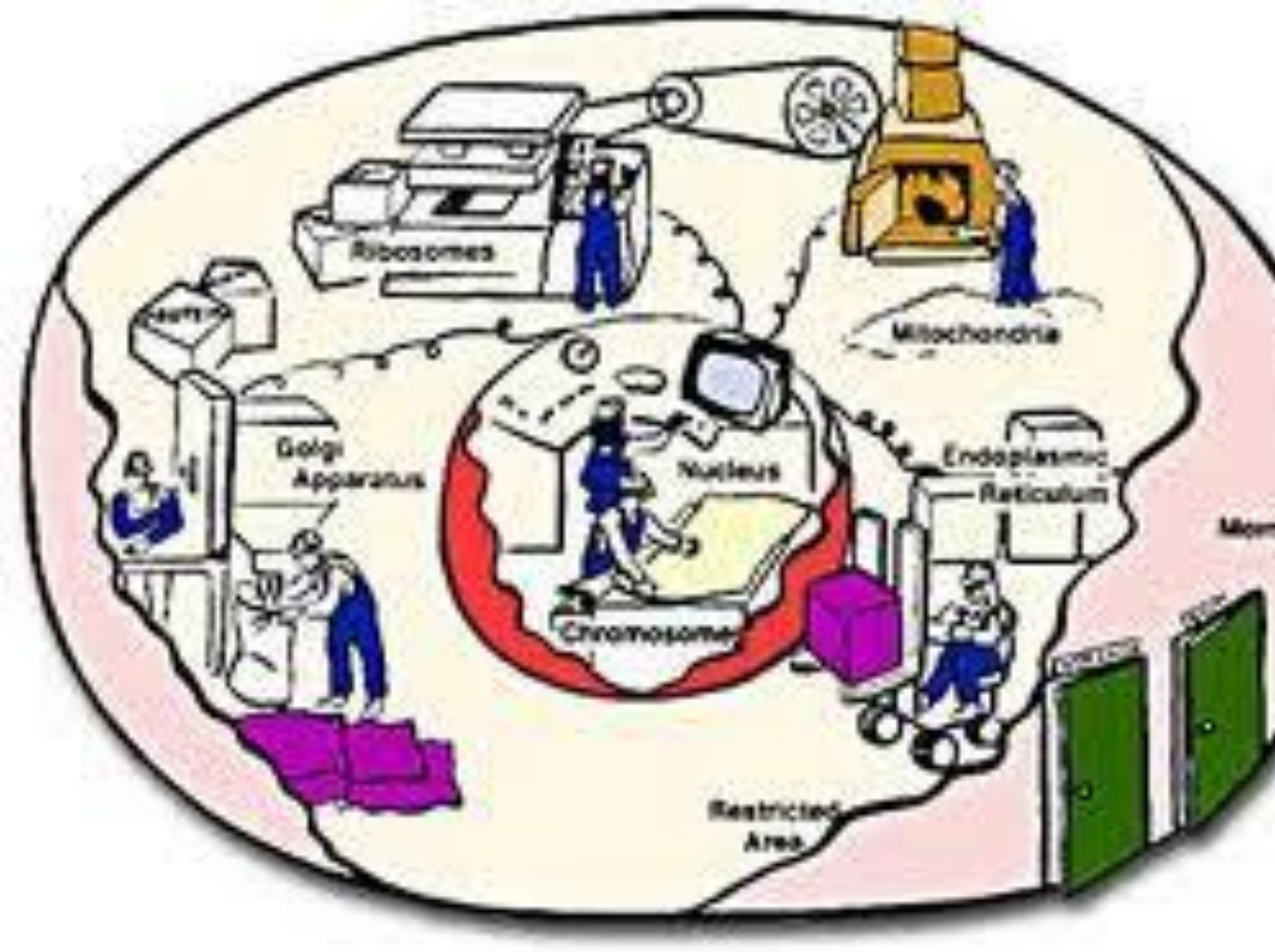
University of Minnesota STREET

Simulating Traffic for Realistic Engineering and Training

Engineering Activities in Biology Class

- Cells as factories
- Protein Synthesis
- Biomimicry/ biomimetic materials
- Artificial limbs
- Artificial intelligence
- Growth models/population models


MET
SER
THR
GLU
SER
CYS
THR
THR


Ribosomes
Mitochondria
Golgi
Apparatus
Nucleus
Endoplasmic
Reticulum
Chromosome
Restricted
Area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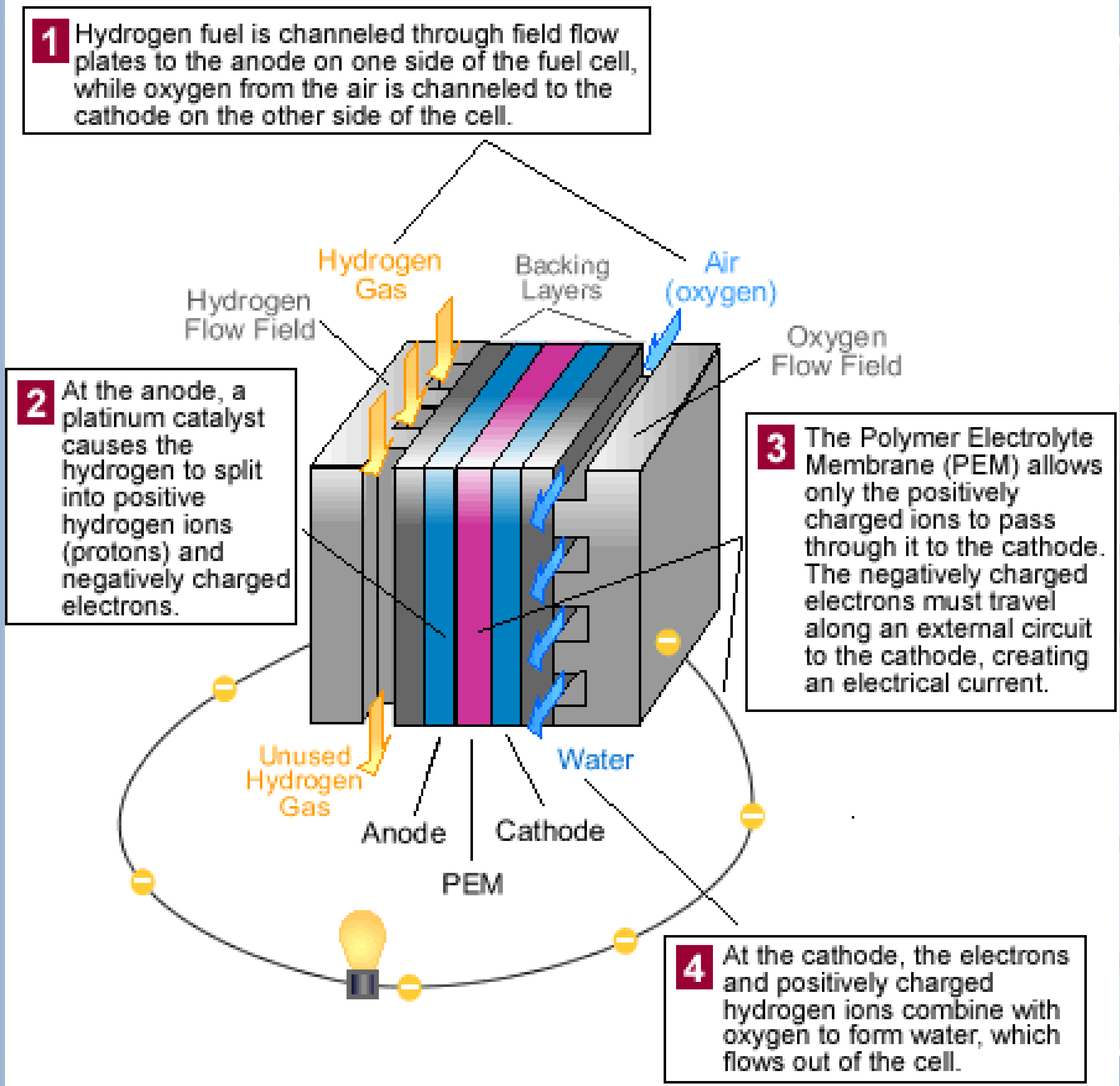
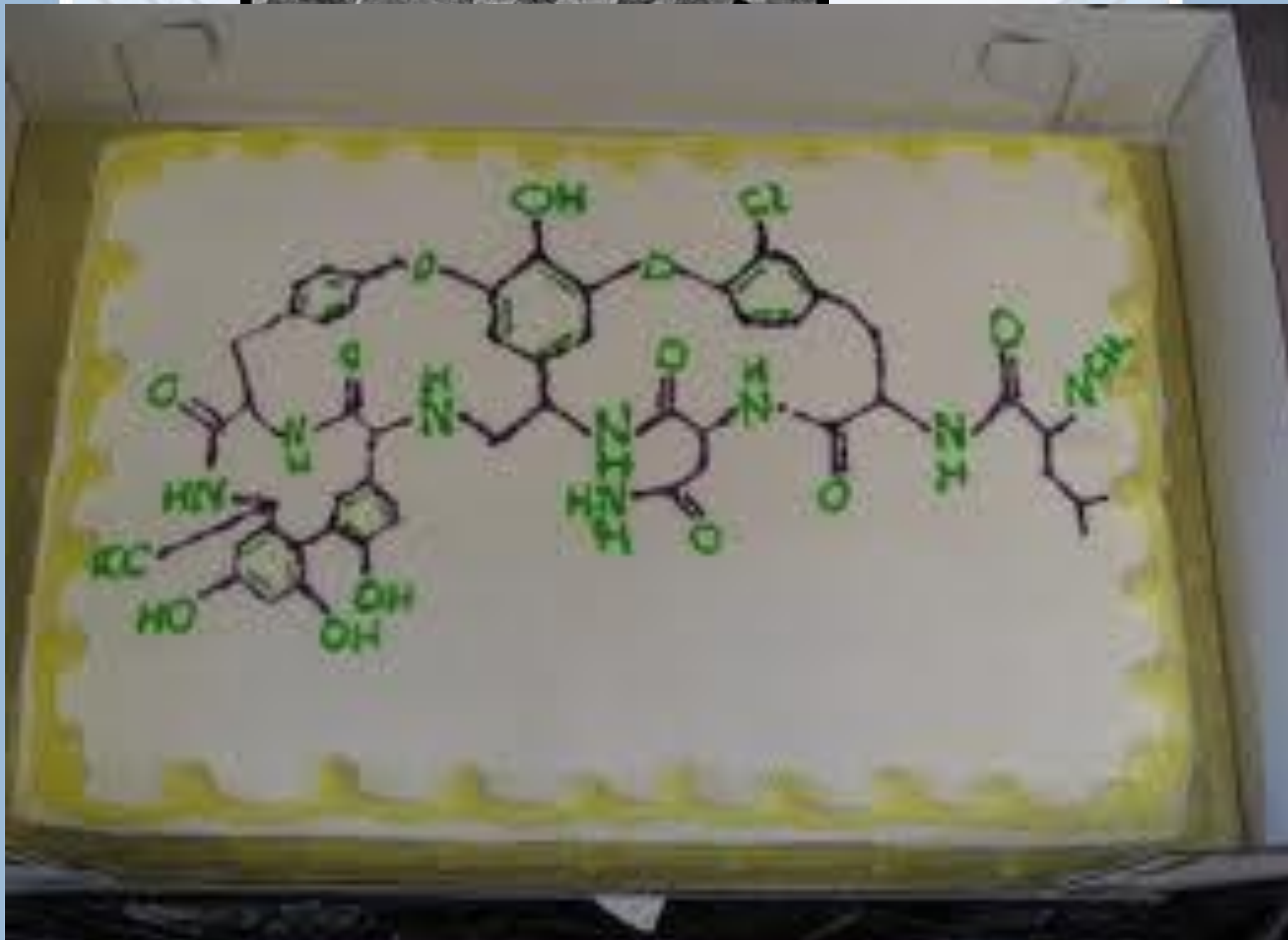
Engineering Activities in Chemistry Class

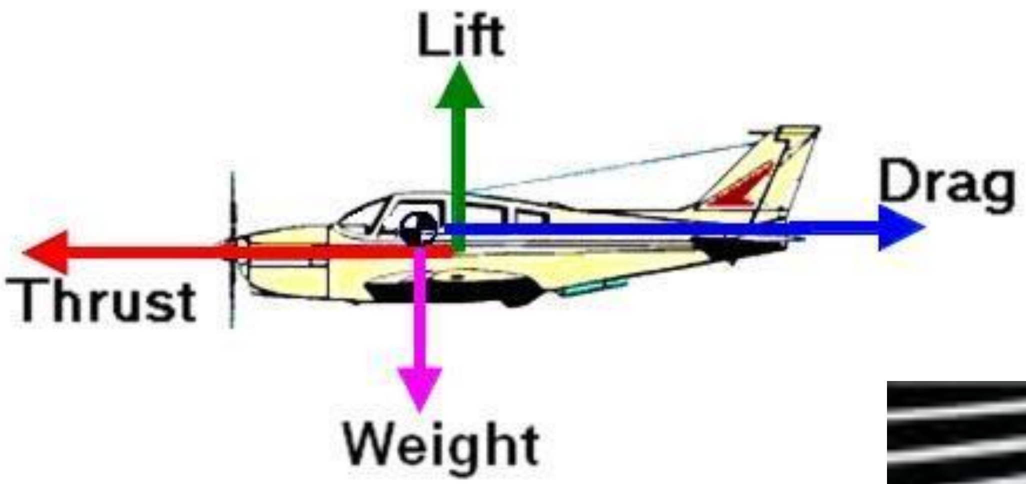
- Baking – reactions, mixtures, heat effects , etc.
- Materials-metals and polymers
- Fuel Cells
- Battery Technology
- Heat Transfer Problems
- Pollution Issues


1 Hydrogen fuel is channeled through field flow plates to the anode on one side of the fuel cell, while oxygen from the air is channeled to the cathode on the other side of the cell.
2 At the anode, a platinum catalyst causes the hydrogen to split into positive hydrogen ions (protons) and negatively charged electrons.
3 The Polymer Electrolyte Membrane (PEM) allows only the positively charged ions to pass through it to the cathode. The negatively charged electrons must travel along an external circuit to the cathode, creating an electrical current.
4 At the cathode, the electrons and positively charged hydrogen ions combine with oxygen to form water, which flows out of the cell.
Hydrogen Gas
Backing Layers
Air (oxygen)
Hydrogen Flow Field
Oxygen Flow Field
Unused Hydrogen Gas
Water
Anode
Cathode
PEM


OH
Cl
HN
HO
OH
OH

Engineering Activities in Physics Class

- **Vehicle Design**
- **Airplane Design**
- **Alternative Energy Technologies**
- **Mechanics of Materials**
- **Mechanics of Artificial Limbs**


Lift
Drag
Thrust
Weight


“…the century ahead poses challenges as formidable as any from millennia past. As the population grows and its needs and desires expand, the problem of sustaining civilization’s continuing advancement, while still improving the quality of life, looms more immediate. ”

“Applying the rules of reason, the findings of science, the aesthetics of art, and the spark of creative imagination, engineers will continue the tradition of forging a better future.”

“Foremost among the challenges are those that must be met to ensure the future itself.”

Grand Challenges for Engineering
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