Towards Transforming Engineering Education
Welcome!
So let’s begin:  

... *with a short quiz.*
You walk into a room and notice that a picture is hanging crooked. As an engineer, you…

a) Straighten it
b) Ignore it
c) Buy a CAD system - spending the next 6 months designing a solar-powered, self-adjusting picture frame
Question 2

Which of the following lies might an engineer offer:

a) "I won't change anything without asking you first"
b) "I'll return your really cool, hard-to-get cable tomorrow"
c) "I need new equipment to do my job"
d) "I'm not the least bit jealous of your new computer"
Question 3

What is your goal for attending this workshop and how would you measure its achievement? (30sec)
Setting the stage...

- **Caution:** Most of the information presented represents the presenter’s opinion and is not an official NSF position.

- **Please Note:** Some of the slides come from Carl Wieman’s presentation at the 2011 TUES / CCLI PI meeting (1/27/11)
Erosion of our national “educational capital” is occurring just when we need more college educated workers.

Baby Boomers retiring.

Increasing skill requirements are necessary for new engineering related jobs.
“Maintaining our leadership in research and technology is crucial to America’s success. But if we want to win the future – if we want innovation to produce jobs in America and not overseas – then we also have to win the race to educate our kids.”

Major Policy questions:
- What is effective teaching, particularly in STEM?
- Can it be developed? How?
- How can we achieve better learning? (evidence!)
Major Advances Over Past 1-2 Decades

Consistent picture ⇒ Achieving learning

Brain research

Engineering Classrooms

Cognitive psychology

Principles of learning help to design experiments and make sense of results - need to understand both what and why
Perceptions About Engineering*

<table>
<thead>
<tr>
<th>Novice</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content:</strong> isolated pieces of information to be memorized</td>
<td><strong>Content:</strong> coherent structure of concepts</td>
</tr>
<tr>
<td>Handed down by an authority, unrelated to real world</td>
<td>Established by experiment, describes nature</td>
</tr>
<tr>
<td><em>Problem solving:</em> simple “template matching” to memorized recipes</td>
<td><em>Problem Solving:</em> systematic concept-based strategies; widely applicable</td>
</tr>
</tbody>
</table>

*Note: consistent across engineers in a discipline*

*C. Wieman adapted from David Hammer*
Relationship of Sense to Meaning

- Does this make sense? *Based on experience*
- Does it have meaning? *Material relevant to the learner*
- Meaning is more significant for longer-term storage
Engineering Education

- 1960’s:
Engineering Education

- Today:
K-12 Classroom

2 3 → 2 + 3 → 5

Given this input... Analyze this system... To get this output...
Engineering Career

Given this input…

Design… this system

w/this desired output…
A Dichotomy

- **In school**: problems almost always are clearly defined, confined to a single discipline, and typically have one right answer.

- **In the workplace**: problems are usually ill-defined, multi-disciplinary, and have several possible answers (**none of which are perfect**).
Sample of the community voice

Acknowledgment: Taken from Cindy Atman’s talk to Danish Centre for Engineering Education Research and Development, June 8, 2007

sample of presentation/publication venues:
ASEE, FIE, ICEE, MDW, iCEER; JEE, AREE, IEEE Transactions on Ed., IJEE, EJEE, JSTEM, JWMSE, Design Studies, and more...
Historic Transformations in Engineering Education

- Science-based engineering
- Computers in the classroom
- Active, team-based learning
- Widespread internet access
- Jam-packed curricula...
What We’ve Learned

- Active classrooms trump passive classrooms
- Reflection fosters re-organization of thinking for deep learning
- Students will remember more if provided less at any given time *(average capacity of working memory is 7 chunks)*

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## Creativity Definition Ranking

<table>
<thead>
<tr>
<th>Topic</th>
<th>Industry</th>
<th>Academia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem identification or articulation</strong></td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Ability to identify patterns of behavior or new combination of actions</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Integration of knowledge across different disciplines</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Ability to originate new ideas</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Comfort with notion of “no right answer”</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Fundamental curiosity</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Originality and inventiveness in work</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td><strong>Problem solving</strong></td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Ability to take risks</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Tolerance of ambiguity</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Ability to communicate new ideas to others</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>

Engineering Workforce Issues

- Need a combination of left/right brain thinking
- Eng jobs require good research, synthesis, and systems integration abilities
- China is trying to become more innovative, while the US is trying to be more rigorous (*it is better to be the US*)
- Need to stimulate, enable and foster creativity
  (*Why did Steve Jobs, Bill Gates & Mark Zuckerberg drop out of college?*)
Today’s Realities

- Engineering schools are heavily influenced by academic traditions that don’t always support the profession’s needs

- We aren’t very effective in preparing students to integrate/organize their knowledge, skills and identity as a professional
Why Engineering Students Leave

- Coursework too restrictive for students’ varied interests
- Lack of role models – especially for women and underrepresented minority students
- Poor advising & teaching – combined with a lack of exposure to engineering early on...leads to discouragement and departure
- Fear of outsourcing
- Lack of connection between what is studied and perceived as exciting practice
Why Are We Here?

- What are the needs of industry?
- Skill set (hard/soft)?
- What is the “right” mix for lifelong learning?
What are the skills needed to do ENG today – different from ABET 2000...

In a world with greater access and viability for lifelong learning (MOOCs, etc.) what might be the best college experience?

With the advent of tools (Matlab, portable hardware, web resources, etc) what changes could be made?
In closing:

- Look to your left
- Look to your right
- Because...

*You are the change agents for the future of engineering*...
Thank you.

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