Towards Transforming Energy Systems Education

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Intent

1) Set the stage for reforming Electric Energy Systems (EES) education
2) Offer a brief perspective of emerging trends in education
3) Provide some background that should be considered - to transform EES education

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)

From: “Measuring Up 2008”
It is getting worse…

Present Challenge
- 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 electric energy/power systems related jobs

The White House Perspective
- “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)

2) Emerging trends in education...

Major Advances Over Past 1-2 Decades

Brain research
- Classroom studies
- Cognitive psychology

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

Brain Research
MRI data related to learning
- Significantly changes the brain; doesn't just add bits of knowledge
- Building proteins, growing neurons => enhance neuron connections...
- Does the brain operate similar to a muscle? More exercise, more wiring?

Perceptions About Science/Engineering*

Novice
- Content: isolated pieces of information to be memorized
- Handled down by an authority, unrelated to real world:
- Problem solving: simple "template matching" to memorized recipes

Expert
- Content: coherent structure of concepts
- Established by experiment, describes nature
- Problem Solving: systematic concept-based strategies, widely applicable

Note: consistent across scientists/engineers in a discipline

“Expert” Competence Research*

Expert competence equals:
- Factual knowledge
- Mental organizational framework => retrieval and application
- Ability to monitor own thinking and learning
("Do I understand this? How can I check?")

New ways of thinking: requires MANY hours of intense practice to develop

Developing Expertise

“Deliberate practice” (Anders Ericsson)
- Do a challenging (but achievable) level task that requires explicit expert-like thinking and intense engagement
- Reflection and guidance on result
- Repeat & repeat & repeat...
- 10,000 hours later...very high level expertise

Brain changes; develops with "exercise"
- "Constructivism", "formative assessment", "self-regulated learning" - all contained in "deliberate practice" framework

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
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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A Potential Class

1. Pre-class intro/exploration activity (research)
2. On-line assessment → JIT in-class planning
3. Preliminary in-class reflective question to stimulate discussion and develop coherence (Concept inventory)
4. Inquiry-based, guided interactive/hands-on activity
5. Response system-based, open-ended question to foster restructuring (clickers)
6. Post-class concept assessment/reinforcement
3) Background considerations...

Energy Systems Workforce Issues

- Industry needs a combination of left/right brain thinking
- EES 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?)

Why Engineering Students Leave

- 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

Creativity Definition Ranking

<table>
<thead>
<tr>
<th>Topic</th>
<th>Industry</th>
<th>Academia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification or articulation</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>1</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 &quot;no right answer&quot;</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>Problem solving</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>

From D. Pink – *A Whole New Mind: Why Right-Brainers Will Rule the Future*

Why Engineering Students Leave

- Poor performance in intro math/science courses
- Coursework too restrictive for students’ varied interests
- Perception that other majors have easier classes and more fun – view engineering as a competitive and uncaring field
- A feeling of isolation from rest of the university – due to the workload, lack of cross disciplinary opportunities

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
An Opportunity

NSF Impact

- NSF uses merit review to select about 10,000 new awards each year from more than 42,000 competitive proposals submitted annually

Solicitation ➔ Proposal ➔ Review ➔ Award ➔ Project

NSF TUES Program (formerly CCLI)

- Title changed to emphasize the special interest in projects that have the potential to transform undergraduate STEM education
- Emphasizes:
  - Materials, processes, or models that enhance student learning
  - Widespread adoption of best classroom practices
  - Adaptation at many sites
  - Exploration of cyberlearning

A Successful Proposal

- Good idea + need
- Right people + infrastructure
- Assessment of outcomes that measure effect on student learning (with goals/objectives linked to evaluation)
- Active dissemination plan
- Efforts to broaden participation of underrepresented groups

Answer Reviewers’ Questions

- What are you trying to accomplish?  } Goals
- What will be the outcomes?
- Why do you believe that you have a good idea?  } Rationale
- Why is the problem important?
- Why is your approach promising?
- How will you manage the project to ensure success?  } Evaluation
- How will you know if you succeed?
- How will others find out about your work?
- How will you interest them?
- How will you excite them?  } Dissemination

This is not a comprehensive list!

Promising Strategies
What Works

- Guided inquiry
- Concept inventories
- Peer-led team learning
- Problem-based learning
- Active recall of information
- Effective use of technology

Process-Oriented Guided Inquiry Learning

- Work in teams to complete specially designed worksheets that guide them through the inquiry process of learning
- Students are given data/information followed by leading questions
- Discuss material - rather than just hear about it
- 3 Phases: Exploration, Concept Invention, Application
- Instructor serves as facilitator, observing and periodically addressing individual and class needs

Peer-Led Team Learning

- Students who do well are trained as “peer leaders” - to guide the efforts of 6-8 students
- Groups meet weekly (outside of class) to work together on challenging problems that help build conceptual understanding and skills
- Problems that can’t be solved easily on one’s own
- PLTL sessions replace traditional recitation sections
- Dept/Institutional support is essential, including logistics and finance

Problem/Service-Based Learning

- Instructor led/facilitated
- Complex problems - open-ended, real world, deliberately vague
- Problems drive concept discovery on a need-to-know basis
- Ideal class size < 30 students (groups of 4-5)
- Concepts will be understood and remembered longer when learned, explored, discussed, applied and tested in a practical context

Technology Example

Engagement

Mobile Studio
Towards Reform/Transformation...

- **3C’s:**
  1) Core (teaching/learning)
  2) Culture (communication/adoption)
  3) Community (local/global)

Why Are We Here?

- **Engage**
- **Educate**
- **Expand the community**
  1. Faculty → Faculty
  2. Admin → Faculty
  3. Faculty → Admin

In closing:

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

You are the change agents for our future energy systems...

Thank you.

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