21st Century Skills: How can you prepare students for the new Global Economy?

Charles Fadel
Global Education Lead

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NSF ATE
Washington, DC
Agenda

- Why 21st Century Skills?
- Why STEM?
- How do we make progress?
The Four-Questions Exercise

- What will the world be like 20 years from now?
- What skills will you need to be successful in that world?
- What were the conditions around your peak learning experiences?
- What would learning look like if it was designed around your answers?
The Perfect Storm

Globalization
Financial Meltdown
Overconsumption
Global Warming

Source: “In the Hollow of a Wave off the Coast at Kanagawa” 18th century by Katsushika Hokusai, Metropolitan Museum of Art, NY
“Climate change” is coming to Education
Magnitude of Competition is Changing

"When China awakens, the world will tremble"
Napoleon Bonaparte

China & India
300M skilled workers
World challenge

Japan
25M skilled workers
US, Europe Challenge

1985

2025
Engineering PhD median salary

- US (CA): $125,200
- Germany: $99,400
- China: $53,700
- India: $39,200

How do you justify 2-3x differential?
“Imagination is more important than Knowledge” – Albert Einstein
Accelerating Change Demands Different Skills

Economy-Wide Measures of Routine and Nonroutine Task Input, 1960–2002

Race up the Value Chain

In More Developed Countries

- Research
- Development
- Design
- Marketing and Sales
- Global Supply Chain Management

Creative Work

In Less Developed Countries

Routine Work
Done by People

Routine Work
Done by Machines

Source: "Tough Choices or Tough Times" 2007, National Center on Education and the Economy
Nature of Work is Changing

<table>
<thead>
<tr>
<th></th>
<th>20th Century</th>
<th>21st Century</th>
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</thead>
<tbody>
<tr>
<td>Number of Jobs</td>
<td>1 – 2 Jobs</td>
<td>10 – 15 Jobs</td>
</tr>
<tr>
<td>Job Requirements</td>
<td>Mastery of One Field</td>
<td>Breadth; Depth in several fields</td>
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</tbody>
</table>

Nature of Work is Changing
m-shaped Individual, not just T-shaped

Broad Knowledge

Single vs Multiple Deep Expertise
The OECD’s View

1. The great collaborators and orchestrators
2. The great synthesizers
3. The great explainers
4. The great versatilists
5. The great personalizers
6. The great localizers

7. *To which I add:* The great innovators

Source: Andreas Schleicher
Growth in baseline qualifications
A world of change

Approximated by percentage of persons with high school or equivalent qualifications in the age groups 55-64, 45-55, 45-44 and 25-34 years

- 1990s
- 1980s
- 1970s
- 1960s

1. Excluding ISCED 3C short programmes
2. Year of reference 2004
3. Including some ISCED 3C short programmes
Increase average performance by 25 PISA points
(Total 115 trillion $)

Potential increase in economic output (bn $)

$133k/person - 3.3X the US Debt

From knowledge to competency
Trelle, Rome, 8 April 2010
The experience of PISA
Andreas Schleicher

OECD
“If an extra 10% of enrollment was engineering, the growth rate would rise 0.5% per year”.

Source: Allocation of Talent, Implications for growth
1990 National Bureau of Economic Research

“Eight studies conducted in recent decades indicate that public investments in science and technology have produced annualized societal returns that range from 20% to 67%.”

Source: “Is America Falling Off the Flat Earth?”
National Academies of Sciences 2007
Increasing STEM education investment by 25% and maintaining spending for 10 years increases average annual US GDP by ~30% (Source: 2010 Cisco/Nature study by Oxford Analytica)
Quite feasible

A 25% increase in STEM spending is significant, but within international norms
4 Tiers of STEM Competency

- Direct Careers
- Indirect Careers
- Influential Professions
- Every Citizen

Neglected - Needs more attention

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STEM Numeracy for the other 95%

Indirect Careers:
- Marketing, Sales, etc (in support of High-Tech, Finance, etc)
- Trade professions (Certifications, HVAC, car mechanics, etc)

Influential Professions:
- Journalists (misleading representations)
- Financiers (probabilities should be mandatory on Wall Street !)
- Lawyers (a lot of billable time spent on low-probability outcomes)
- Politicians (non-linearities associated with global warming)
- Doctors (prescribing appropriate treatment)

Every citizen: and enrolling Liberal Arts colleges
- Understanding risk: Personal finance; Health (cancer; airbag; vaccination; cellphones; flying…); etc
- Understanding Life: log curve, exp-curve, n-curve, S-curve, bell-curve, etc
Math or Numerology? Cosmology or Mythology? Evolution or Creationism? etc.

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World Future Society
Top 10 Breakthroughs Transforming Life over the next 20-30 years

1. Alternative energy
2. Desalination of water
3. Precision farming
4. Biometrics
5. Quantum computers
6. Entertainment on demand
7. Global access
8. Virtual education
9. Nanotechnology
10. Smart Robots
Percentage of science graduates

Korea | Japan | EU | United States
U.S. Trailing and Falling Further Behind

We have many friends among tall countries and short countries alike

Although some are hiding weapons to attack us
PISA - Canada

2006:
#3 in Science
#4 in Reading
#5 in Math

2nd-highest combined scores
Comparison with India and China

Engineering, CS and IT Degrees Awarded in 2004

United States: 84,898
India: 103,000
China: 292,569

Number of Bachelors Degrees: United States 137,437, India 112,000
Number of Subbaccalaureate Degrees: United States 292,569, India 112,000

Source: Duke University, Framing the Engineering Outsourcing Debate, Dec. 2005
Adjusted to population size

Country

- United States: 289.3 (Bachelors) + 179.0 (Subbaccalaureate) = 468.3
- India: 95.4 (Bachelors) + 0.7 (Subbaccalaureate) = 96.1
- China: 271.1 (Bachelors) + 44.6 (Subbaccalaureate) = 315.7

Source: Duke University, Framing the Engineering Outsourcing Debate, Dec. 2005
IN LOW-WAGE COUNTRIES, ON AVERAGE ONLY 13% OF UNIVERSITY GRADUATES ARE SUITABLE TO WORK IN A MULTINATIONAL COMPANY

"Of 100 graduates with the correct degree, how many could you employ if you had demand for all?"

%  

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<thead>
<tr>
<th></th>
<th>Max</th>
<th>Min</th>
<th>Avg</th>
<th>Weighted average</th>
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<tbody>
<tr>
<td>Engineer</td>
<td>50</td>
<td>10</td>
<td>30</td>
<td>17</td>
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<tr>
<td>Finance/accounting</td>
<td>50</td>
<td>13</td>
<td>30</td>
<td>19</td>
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<tr>
<td>Life science researcher</td>
<td>50</td>
<td>10</td>
<td>30</td>
<td>14</td>
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<tr>
<td>Analyst</td>
<td>50</td>
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<td>15</td>
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<tr>
<td>Generalist</td>
<td>30</td>
<td>3</td>
<td>19</td>
<td>10</td>
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</tbody>
</table>

*Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Czech Republic, Estonia, Hungary, India, Indonesia, Latvia, Lithuania, Malaysia, Mexico, Philippines, Poland, Russia, Romania, Slovakia, Slovenia, South Africa, Thailand, Turkey, Ukraine, Venezuela, Vietnam.

Source: Interviews with HR managers, HR agencies and heads of global resourcing centers; McKinsey Global Institute analysis

Quality matters, not just quantity

McKinsey report concluded that only 10% of Chinese engineers and 25% of Indian engineers can compete in the global outsourcing arena.

### 19 out of the top 20 Bachelor-level salaries are STEM-related

<table>
<thead>
<tr>
<th>Best Undergrad College Degrees By Salary</th>
<th>Starting Median Salary</th>
<th>Mid-Career Median Salary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace Engineering</td>
<td>$59,600</td>
<td>$109,000</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>$65,700</td>
<td>$107,000</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>$61,700</td>
<td>$105,000</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>$60,200</td>
<td>$102,000</td>
</tr>
<tr>
<td>Economics</td>
<td>$50,200</td>
<td>$101,000</td>
</tr>
<tr>
<td>Physics</td>
<td>$51,100</td>
<td>$98,800</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>$58,900</td>
<td>$98,300</td>
</tr>
<tr>
<td>Computer Science</td>
<td>$56,400</td>
<td>$97,400</td>
</tr>
<tr>
<td>Industrial Engineering</td>
<td>$57,100</td>
<td>$95,000</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>$53,400</td>
<td>$94,500</td>
</tr>
<tr>
<td>Statistics</td>
<td>$48,600</td>
<td>$94,500</td>
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<tr>
<td>Biochemistry</td>
<td>$41,700</td>
<td>$94,200</td>
</tr>
<tr>
<td>Mathematics</td>
<td>$47,000</td>
<td>$93,600</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>$55,100</td>
<td>$93,000</td>
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<tr>
<td>Construction Management</td>
<td>$53,400</td>
<td>$89,600</td>
</tr>
<tr>
<td>Finance</td>
<td>$48,500</td>
<td>$89,400</td>
</tr>
<tr>
<td>Management Information Systems</td>
<td>$51,900</td>
<td>$87,200</td>
</tr>
<tr>
<td>Computing and Information Systems</td>
<td>$50,900</td>
<td>$86,700</td>
</tr>
<tr>
<td>Geology</td>
<td>$45,100</td>
<td>$84,200</td>
</tr>
<tr>
<td>Chemistry</td>
<td>$42,900</td>
<td>$82,300</td>
</tr>
</tbody>
</table>

Top Bachelor’s Degrees in Demand

1. Finance
2. Accounting
3. Mechanical Engineering
4. Business Administration/Mgmt.
5. Electrical Engineering
6. Computer Science
7. Information Sciences & Systems
8. Marketing/Marketing Mgmt.
9. Computer Engineering
10. Chemical Engineering
11. Management Information Systems

Source: Job Outlook 2010, National Association of Colleges and Employers
**Lowest-paying … yet very satisfying !**

<table>
<thead>
<tr>
<th>Field</th>
<th>Starting Salary/Yr</th>
<th>Mid-career salary/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drama</td>
<td>$35,600</td>
<td>$56,600</td>
</tr>
<tr>
<td>Fine arts</td>
<td>$35,800</td>
<td>$56,300</td>
</tr>
<tr>
<td>Hospitality and tourism</td>
<td>$37,000</td>
<td>$54,300</td>
</tr>
<tr>
<td>Education</td>
<td>$36,200</td>
<td>$54,100</td>
</tr>
<tr>
<td>Horticulture</td>
<td>$37,200</td>
<td>$53,400</td>
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<tr>
<td>Spanish</td>
<td>$35,600</td>
<td>$52,600</td>
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<tr>
<td>Music</td>
<td>$34,000</td>
<td>$52,000</td>
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<tr>
<td>Theology</td>
<td>$34,800</td>
<td>$51,500</td>
</tr>
<tr>
<td>Elementary education</td>
<td>$33,000</td>
<td>$42,400</td>
</tr>
<tr>
<td>Social work</td>
<td>$33,400</td>
<td>$41,600</td>
</tr>
</tbody>
</table>
Schooling vs Real-World

“...school learning is abstract, theoretical and organized by disciplines while work is concrete, specific to the task, and organized by problems and projects...”

OECD, “Learning for Jobs”
<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Skills</th>
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</thead>
<tbody>
<tr>
<td>English Language (spoken)</td>
<td>Critical Thinking/Problem Solving</td>
</tr>
<tr>
<td>Reading comprehension (English)</td>
<td>Communications (oral &amp; written)</td>
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<tr>
<td>Writing (English)</td>
<td>Collaboration/Teamwork</td>
</tr>
<tr>
<td>Mathematics</td>
<td>Diversity</td>
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<tr>
<td>Science</td>
<td>Information Technology Applications</td>
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<tr>
<td>Government/Economics</td>
<td>Leadership</td>
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<tr>
<td>Humanities/Arts</td>
<td>Lifelong Learning/Self-Direction</td>
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<tr>
<td>Foreign Languages</td>
<td>Professionalism/Work Ethic</td>
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<tr>
<td>History/Geography</td>
<td>Ethics/Social Responsibility</td>
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</tbody>
</table>

Source: “Are they really ready to work?” report by the Conference Board, P21 et al
Has your organization identified these skills as priorities for employee development, talent management, and succession planning?

<table>
<thead>
<tr>
<th>Skill</th>
<th>Agree/Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical thinking</td>
<td>73.3%</td>
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<tr>
<td>Communication</td>
<td>79.2%</td>
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<tr>
<td>Collaboration</td>
<td>72.3%</td>
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<tr>
<td>Creativity/innovation</td>
<td>66.6%</td>
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</tbody>
</table>

Source: AMA/P21 2010 Critical Skills Survey, released April 2010
“This is a story about… whether an entire generation of kids will fail to make the grade in the global economy because they can’t think their way through abstract problems, work in teams, distinguish good information from bad, or speak a language other than English.”

*How to Build a Student for the 21st Century*, TIME Magazine, December 18, 2006
“I'm calling on our nation... to develop standards and assessments that don't simply measure whether students can fill in a bubble on a test, but whether they possess 21st century skills like problem-solving and critical thinking and entrepreneurship and creativity”

U.S. President Barack Obama, March 2009
Voter Attitudes toward 21st Century Skills

“21st century skills are important for schools to teach.”
Current State Partners

- Arizona
- Illinois
- Iowa
- Kansas
- Louisiana
- Maine
- Massachusetts
- Nevada
- New Jersey
- North Carolina
- Ohio
- South Carolina
- South Dakota
- West Virginia
- Wisconsin
Global Interest

Signatories:

Australia
England
Finland
Portugal
Singapore
USA

http://www.atc21s.org/
Teaching & Learning Challenges

WHAT is taught:

• **Relevance** (applicability, significance) to real-world (for motivation, and employability)

• **Skills**, not just Knowledge (critical thinking, creativity, etc)
“Please, Ms. Sweeney, may I ask where you’re going with all this?”
### Disciplines and Relevant Mathematics Topics

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<tbody>
<tr>
<td>Matrices, Operations, Vectors etc</td>
<td>Complex systems, Control, Game theory, etc</td>
<td>Analysis, Transforms, Polynomials, etc</td>
<td>Automata, Graphs, Computational maths etc</td>
<td>Sets, Logic etc</td>
<td>Curves, Dimensions, Transformations, Trigonometry, etc</td>
<td>Arithmetic operations, Fractions, etc</td>
<td>Distributions, Analysis, Estimation, etc</td>
<td>Knots, Figures, Folding, Spaces, etc</td>
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<td>Anthropology</td>
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"Numbers and probability provide the basis for statistics, which, together with Logic, constitute the foundation of the Scientific Method"  
John Allen Paulos
Depth vs breadth is a choice

Example: Ancient Greece
MIT – Mechanical Engineering

Did not learn
Learned elsewhere
Learned on the job
Graduate school
MIT undergrad

Learned at MIT
Used pervasively

Why does it matter?

Frequency of use

- pervasively
- never
- lead/innovate
- none

Expected proficiency
"Making Engineers Smart—and Savvy
New MIT program grafts social skills onto problem solvers"

“The program is designed to give budding engineers skills that go beyond the technical—risk assessment, decision making, interpersonal relations, resourcefulness, and flexibility”

Source: http://spectrum.ieee.org/at-work/education/making-engineers-smartandsavvy by Susan Karlin /May 2010
• Collaborative Learning - work in groups of 3
• Networked laptops
• Media-rich software
• Extensive course notes
• **Assessment** showing learning gains 2x higher than traditional instruction

Expanding the Mindset

What is engineering?

- People
- Problem
- Concept
- Specifications
- Design
- Prototype
- Product
- Market

Narrow Definition

User-Oriented Design

Design Nature

Modeling Compartment Systems

Fundamentals of Entrepreneurship

Courtesy of Olin President Richard Miller
First year Student Engagement

Mean Score (in Std Dev from NSSE Mean)

- Level of Academic Challenge
- Active and Collaborative Learning
- Student-Faculty Interaction
- Enriching Educational Experiences
- Supportive Campus Environment

Olin College
Engineering
Liberal Arts
NSSE 2009

Courtesy of Olin President Richard Miller
20th Century Framework

Content

Assessment
21st Century Framework

21st Century Student Outcomes and Support Systems

- Learning and Innovation Skills
- Core Subjects and 21st Century Themes
- Information, Media, and Technology Skills
- Life and Career Skills

- Standards and Assessments
- Curriculum and Instruction
- Professional Development
- Learning Environments
# 21st Century Skills Framework

<table>
<thead>
<tr>
<th>Core Subjects</th>
<th>21st Century Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language/Reading</td>
<td>Global Awareness</td>
</tr>
<tr>
<td>World Language(s) incl. English</td>
<td>Financial, Economic, Business and Entrepreneurial literacy</td>
</tr>
<tr>
<td>Arts</td>
<td>Civic Literacy</td>
</tr>
<tr>
<td>Geography</td>
<td>Health Literacy</td>
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<tr>
<td>History</td>
<td>Environmental Literacy</td>
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<tr>
<td>Mathematics</td>
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<tr>
<td>Science</td>
<td></td>
</tr>
<tr>
<td>Government/Civics</td>
<td></td>
</tr>
</tbody>
</table>
21st Century Skills Framework

Learning & Innovation Skills
- Critical Thinking & Problem Solving
- Creativity & Innovation
- Communication & Collaboration

Information, Media & Technology Skills
- Information Literacy
- Media Literacy
- ICT (Information, Communications & Technology) Literacy

Life & Career Skills
- Flexibility & Adaptability
- Initiative & Self-Direction
- Social & Cross-Cultural Skills
- Productivity & Accountability
- Leadership & Responsibility
### Yes it is a Matrix

<table>
<thead>
<tr>
<th>CONTENT (Core subjects)</th>
<th>English, Reading &amp; Language Arts</th>
<th>World Languages</th>
<th>Arts</th>
<th>Mathematics</th>
<th>Science</th>
<th>Geography</th>
<th>History</th>
<th>Gov’t &amp; Civics</th>
<th>Economics</th>
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- **21st Century Themes (multi-disciplinary)**
  - Global awareness
  - Financial literacy
  - Civic literacy
  - Health literacy
  - Environmental literacy
Interdisciplinarity

- Like real life!
- *Complementary* to subject-specificity
- Helps thread Skills throughout
- Fosters creativity (richness of future innovations)

→ Balance between single-subjects and interdisciplinarity
Implications – Curriculum & Instruction:
Rebalance Direct Instruction with Projects

Note: Projects include designs, inquiries, simulations, etc.
Rebalancing Education

Teacher-directed
Direct Instruction
Knowledge
Content
Basic Skills
Theory
Curriculum
Individual
Classroom
Summative Assessed
Learning for School

Student-directed
Collaborative Construction
Skills
Process
Higher-order Thinking
Practice
Life Skills
Group
Community
Formative Evaluation
Learning for Life

A Better Balance
For Math specifically

- Profound yet simple concepts are not digested:
  - linear vs geometric progression
  - growth % more important than actual value
  - $5k expense focus vs $1Trillion deficit
  - etc

- Too little emphasis on real-life disciplines (Stats/Probabilities)
For Math specifically

- **Creativity:** Skills are not equal in terms of economic impact, so:
  - solve an exercise
  - solve a problem
  - solve a class of problems
  - use non-standard solutions
  - create new problems or classes of problems, with their solutions

  "The formulation of a problem is often more essential than its solution"
  
  Albert Einstein

For Math specifically (2)

- **STEAM**: STEM with attention to Arts for Creativity boost
  - Recreational Mathematics working with Arts dept:
    - Tessellations, tangrams, folding, puzzles, fractals, etc
    - “Gödel, Escher, Bach” (patterns)
Non-Standard Solutions - Niels Bohr urban legend...


"Describe how to determine the height of a skyscraper with a barometer."

"You tie a long piece of string to the neck of the barometer, then lower the barometer from the roof of the skyscraper to the ground.

"you could take the barometer up to the roof of the skyscraper, drop it over the edge, and measure the time it takes to reach the ground.

"Or if the sun is shining you could measure the height of the barometer, then set it on end and measure the length of its shadow. Then you measure the length of the skyscraper's shadow, and thereafter it is a simple matter of proportional arithmetic.

"you could tie a short piece of string to the barometer and swing it like a pendulum, first at ground level and then on the roof of the skyscraper. The height is worked out by the difference in the gravitational restoring force.

"Or if the skyscraper has an outside emergency staircase, it would be easier to walk up it and mark off the height of the skyscraper in barometer lengths, then add them up."

"of course, you could use the barometer to measure the air pressure on the roof of the skyscraper and on the ground, and convert the difference in millibars into feet to give the height of the building."

"undoubtedly the best way would be to knock on the janitor's door and say to him 'If you would like a nice new barometer, I will give you this one if you tell me the height of this skyscraper'."

... has merit of showing multiplicity of approaches
Social Factors need to be addressed

- Fear of Math & Science – teacher- and parent-dependent
- Scorn of “geek” – society-dependent
- Fears of offshoring - overblown but present

The social factors are the largest
Move to Student-Centric Teaching and Learning

Teacher-Centric
- Auditory
- Passive

Learner-Centric
- Auditory
- Visual
- Interactive
- Collaborative
- Reflective
- Analytical
- Synthetic
- Creative
Today’s Students…

- Are *clamoring* for relevance and applicability of what they learn

- Are begging to be taught differently
  
  Their lives are a social network
  Technology is pervasive
Most preferred ways to learn

In which three of the following ways do you prefer to learn?

- In groups: 55%
- By doing practical things: 39%
- With friends: 35%
- By using computers: 31%
- Alone: 21%
- From teachers: 19%
- From friends: 16%
- By seeing things done: 14%
- With your parents: 12%
- By practising: 9%
- In silence: 9%
- By copying: 8%
- At a museum or library: 5%
- By thinking for yourself: 6%
- From others: 3%
- Other: 1%

Base: All pupils (2,417)
Source: Ipsos MORI for BECTA, 2007
What Did Dewey Advocate?

- Experiential education
- Self-directed learning
- Group & social learning
- Inquiry
- Growth & adaptability
- Citizens in society
Ancient Wisdom

Confucius (551-479 BC):
“I hear and I forget, I see and I remember, I do and I understand”

Aristotle (384-322 BC):
“The proof that one knows something is that they can teach it”

Michel de Montaigne (1533-1592 AD):
“rather a mind shaped than a head full”
“The authors have done nothing less than provide a bold framework for designing a 21st century approach to education, an approach aimed at preparing all of our children to successfully meet the challenges of this brave, new world.”

Paul Reville, Secretary of Education, Commonwealth of Massachusetts; former director of the Education Policy and Management Program, Harvard Graduate School of Education

“It’s about time that we have such an accessible and wise book about the 21st century skills that so many companies, policymakers, and educators are talking about”

Roy Pea, Professor, Education and the Learning Sciences, Stanford University

http://www.21stcenturyskillsbook.com