

Educating Engineers and Scientists For The 21st Century

JUNBA 2013, January 11, 2013

**Jim Plummer, Dean
Stanford School of Engineering**

The Roles of Engineering Schools in the 21st Century

- **Provide a quality technical education in a way that attracts the best and brightest young people.**
- **Teach students how to be entrepreneurial, creative, innovative, to “think out of the box”.**
- **Create technologies and ideas that can “reinvent” existing companies or spawn new companies.**
- **Provide ongoing professional education easily accessible to working professionals.**
- **Engineering schools have focused mainly on the first bullet historically. We need to work on all of them.**

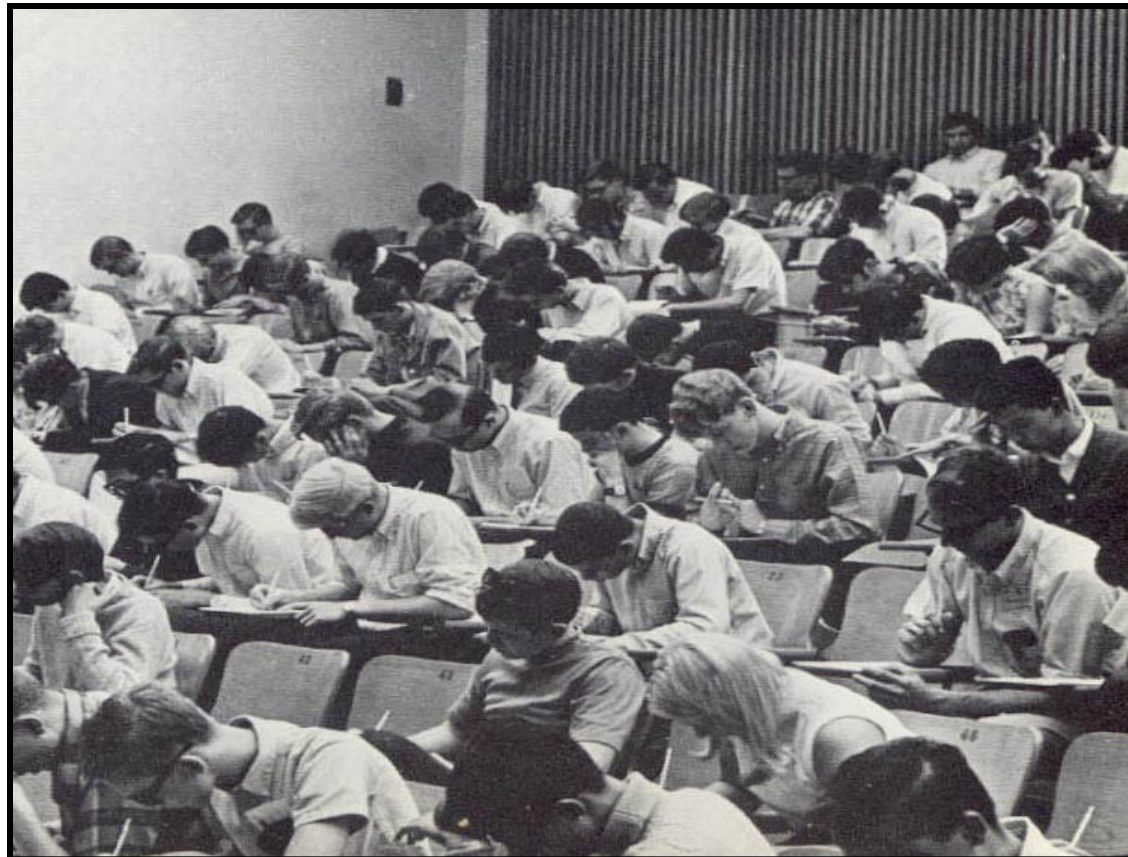
Educating Engineers/Scientists For The 21st Century

Outline

- Reinventing engineering education – how do we get more young people interested?
- Going beyond technical skills – what else do our students need to know to be successful?
- Research – what should universities work on to create the next wave of innovation?
- Online education.

Was This Your Undergraduate Experience?

- Science based - lots of math, physics, chemistry
- Science, math first, engineering later.
- Focused on preparing students to be “immediately productive” in a corporate environment.



What Has Changed?

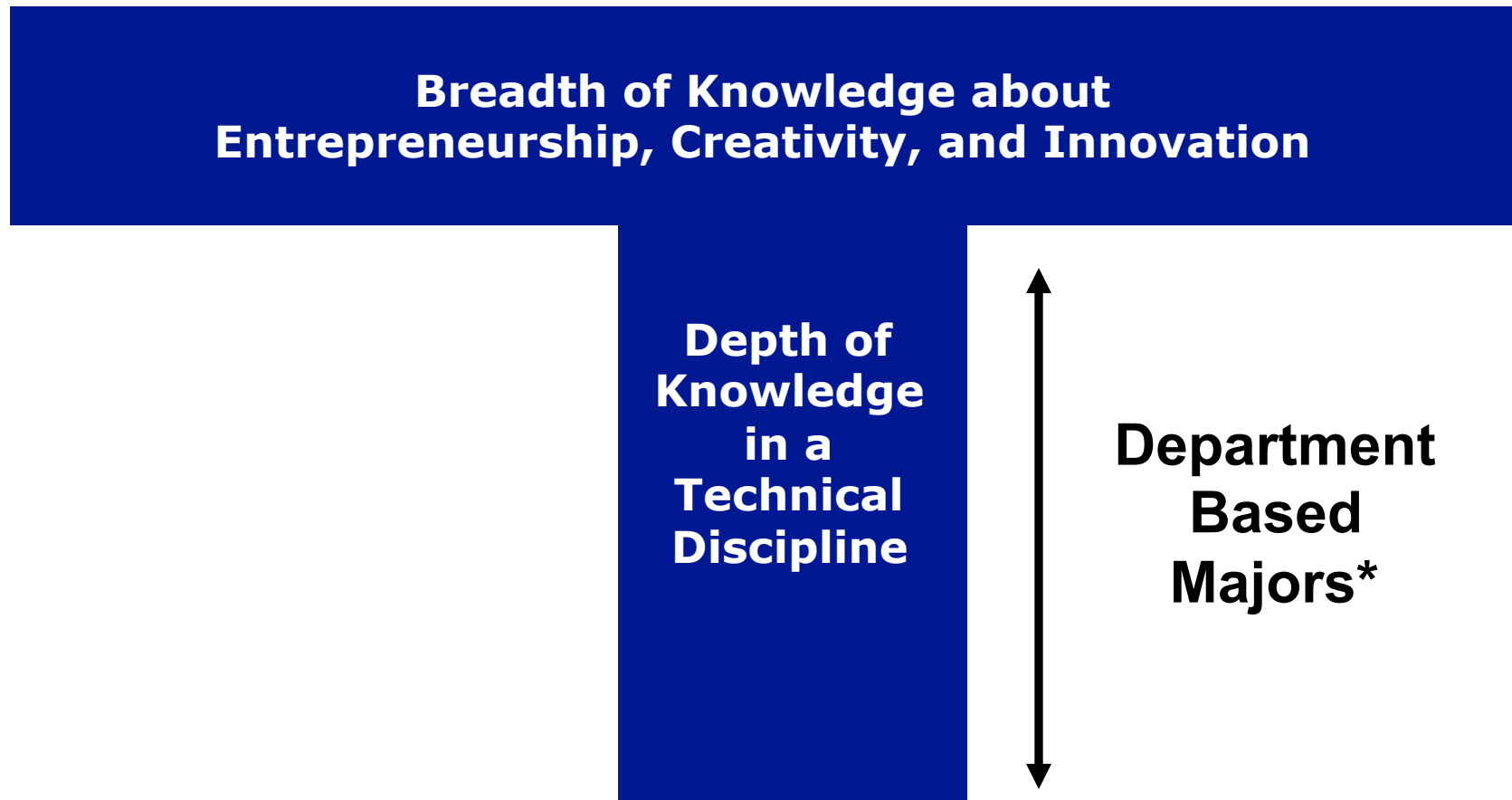
- **Internet** - information anytime, anywhere. Students today go first to the internet for solutions to problems, help with understanding concepts etc.
- **Class notes, lectures**, on virtually any topic are widely available on the internet.
- **Social networking tools** are becoming very useful to students in getting help from experts or other students.
- **Careers** - global, unpredictable, lifelong learning essential.
- **Technology** - rapid changes, innovation wins. Practicing engineers don't have the luxury of taking quarter or semester long courses.

Educating Engineers/Scientists For The 21st Century

What are the critical skills our students need?

- **Technical depth in a particular field**
- **Creativity and innovation**
- **Entrepreneurial Outlook**
- **Communication skills**
- **Ability to work well as a member of a diverse team**
- **Global knowledge and experience**
- **Commitment to life-long learning**

T-Shaped People



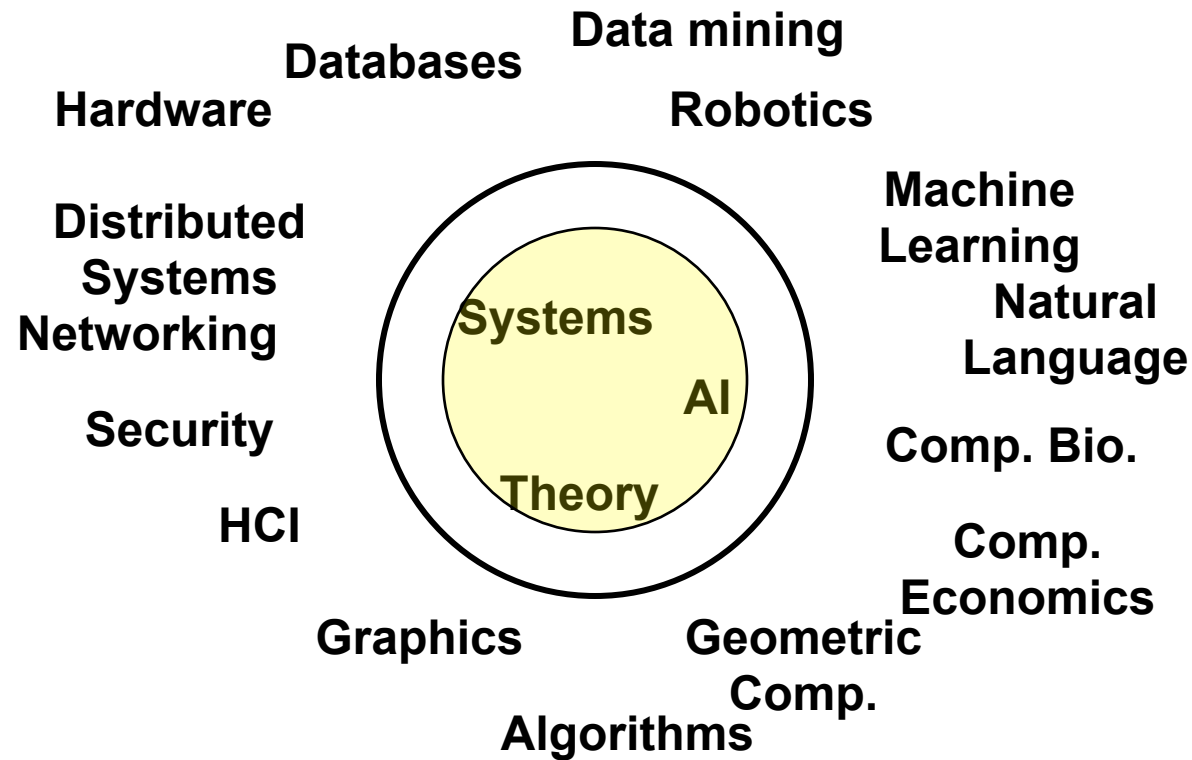
*** Engineering majors change continuously because technical knowledge evolves so rapidly.**

Department Based Majors

Revising The Undergraduate CS Curriculum

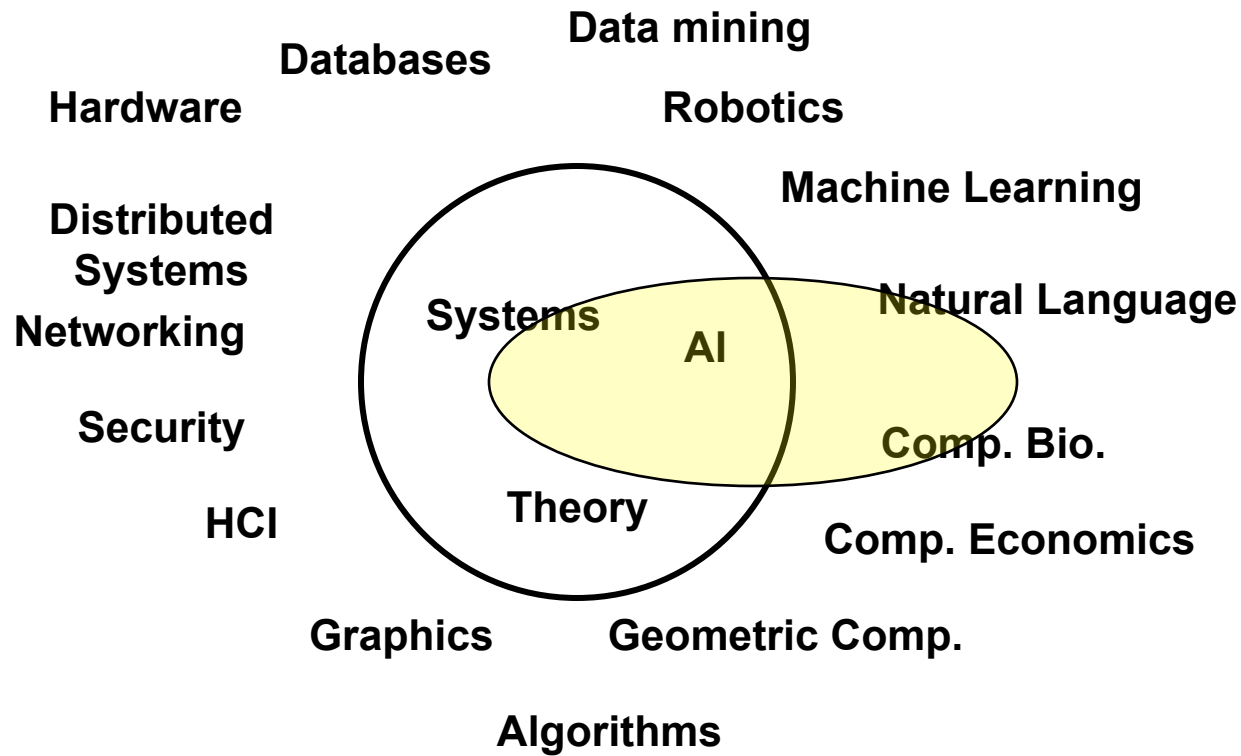
- **Beginning with the .com crash a decade ago, CS departments in the US saw a large decline in majors.**
- **Perception that CS career = cubicle + writing code.**
- **Perception that all software jobs were being outsourced to India.**
- **Neither of these was correct but UG curricula were focused on learning to write computer programs and did little to connect those skills to interesting applications. Programming is the means, not the end.**

“Footprint” CS Students Typically See



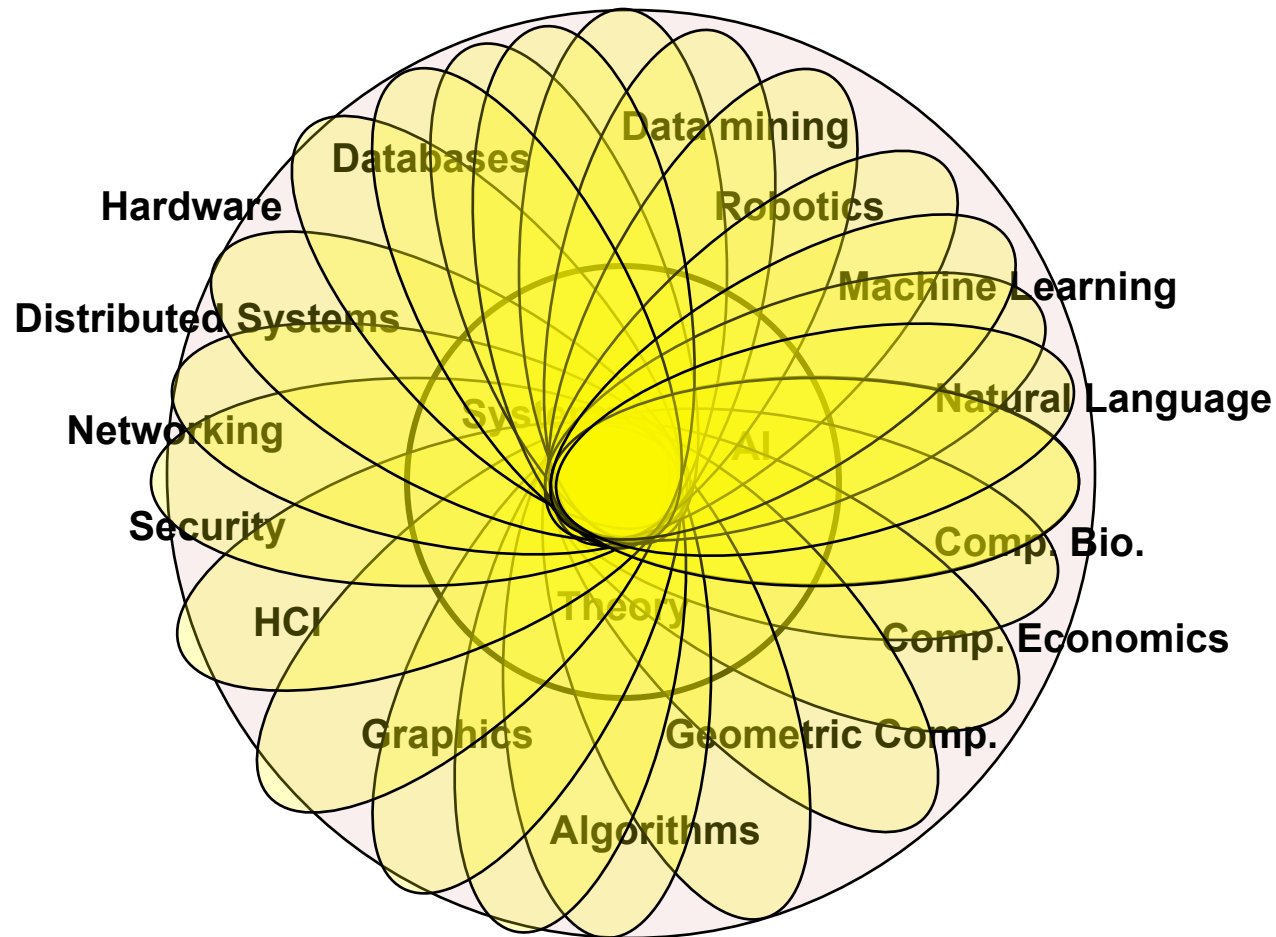
- **“Foundational” topics only increase in scope, so the easy thing to do is to further expand the core (yellow region).**
- **The main thing this accomplishes in engineering programs is to lose more students to other majors.**

Tracks Allow More Depth...

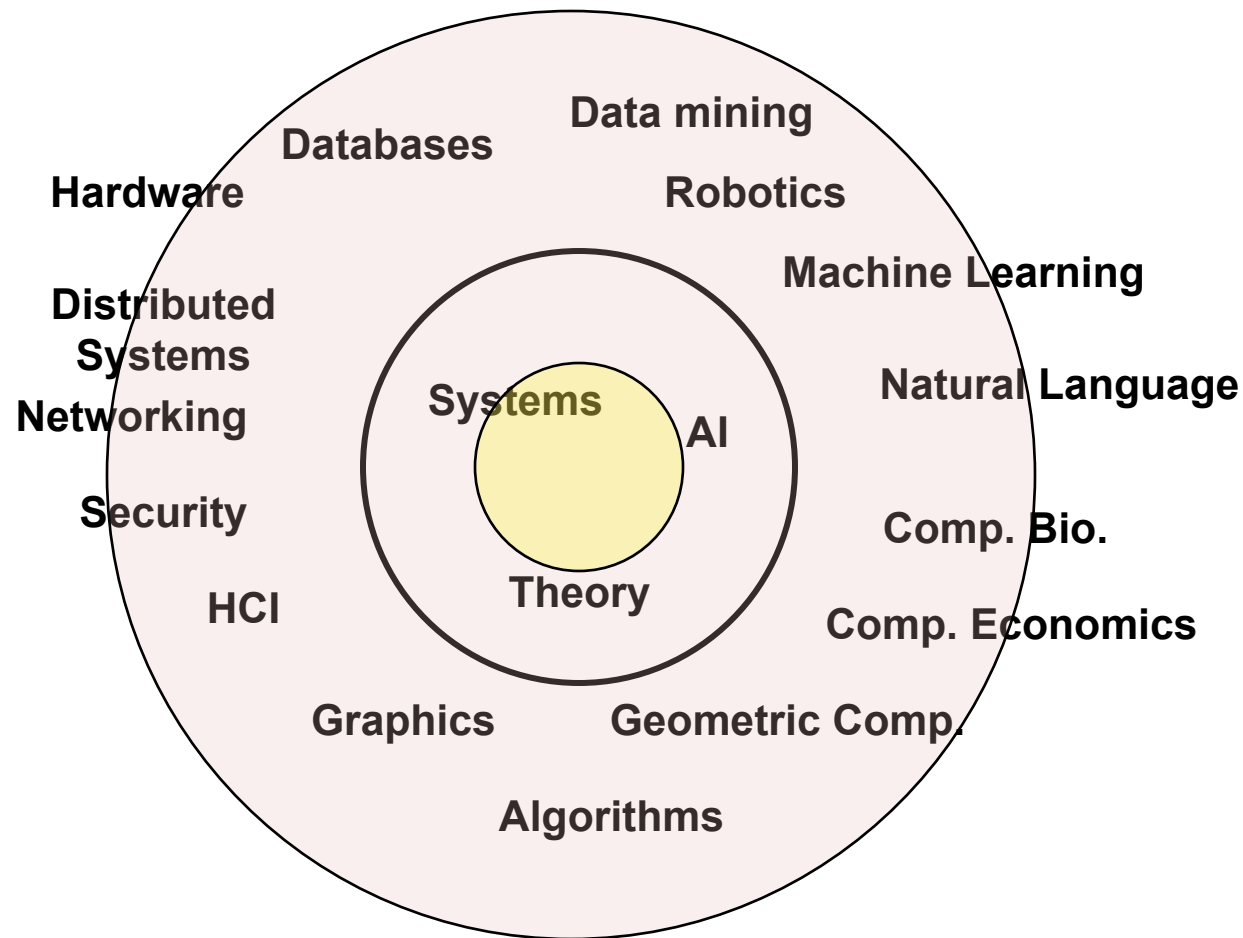


Total amount of material covered must remain the same

...in a More Diverse Set of Areas

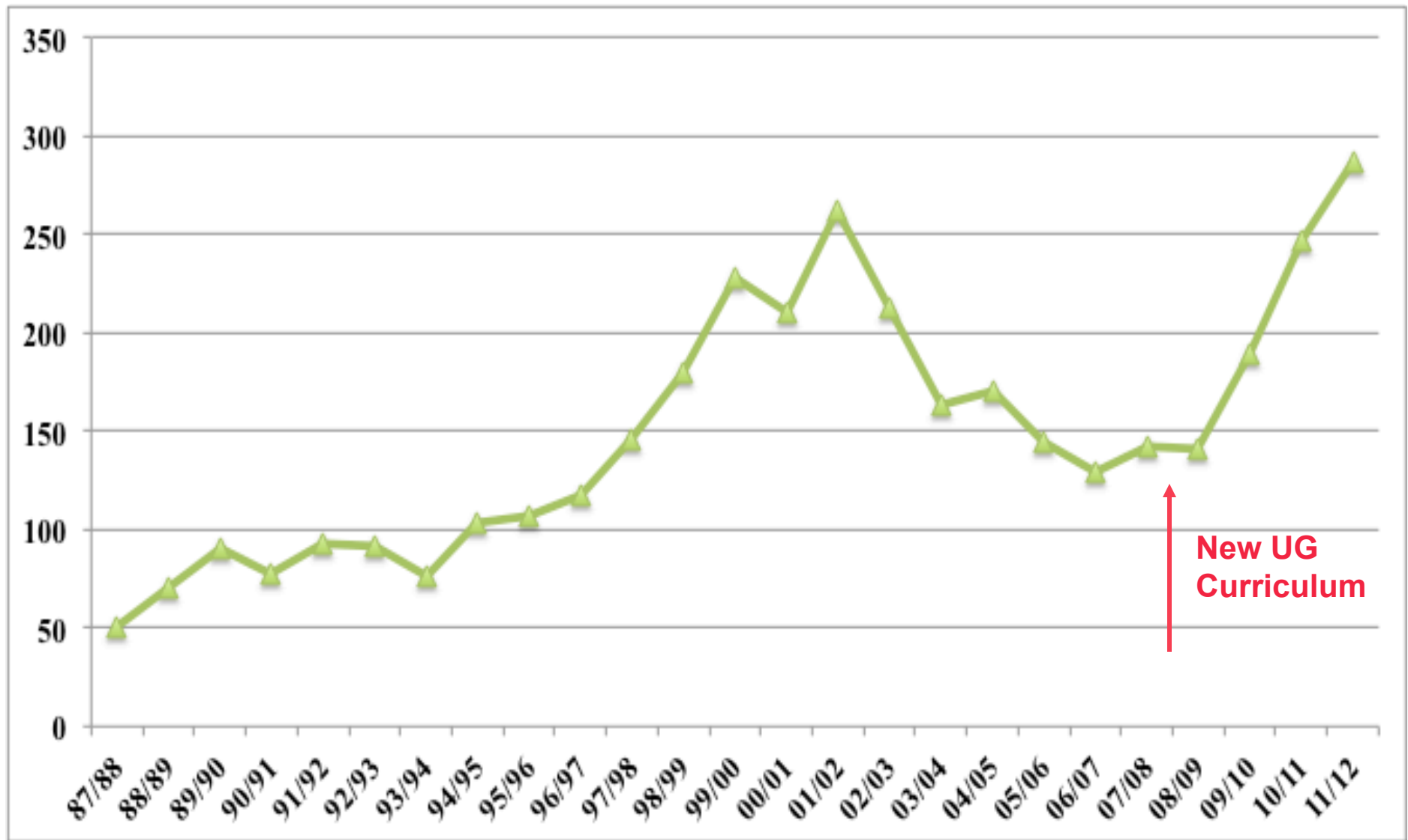


Total Potential “Footprint” is Larger

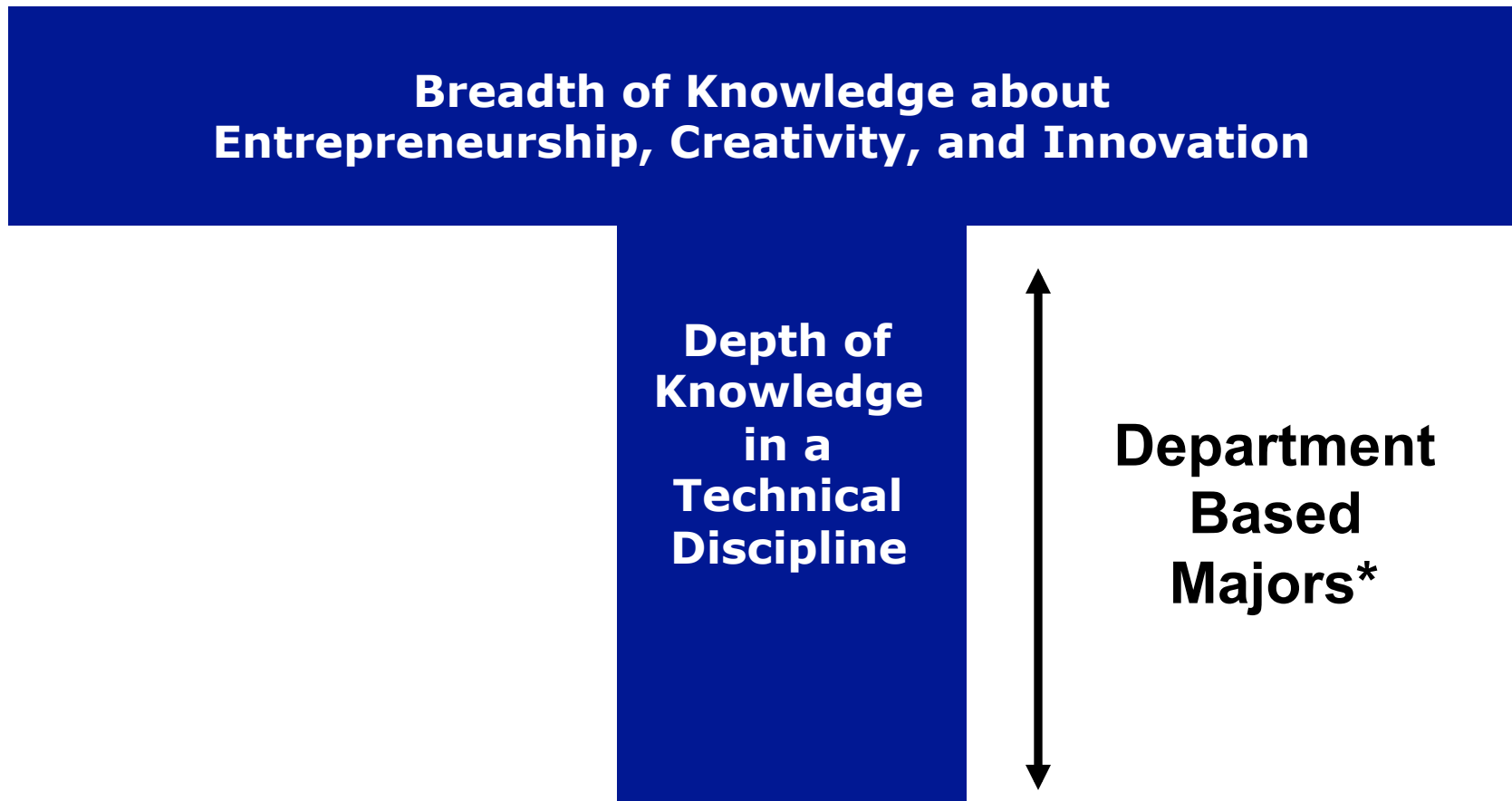


**Core material everyone sees is streamlined to accommodate.
This has implications for “lifelong” education.**

C.S. Undergraduate Majors

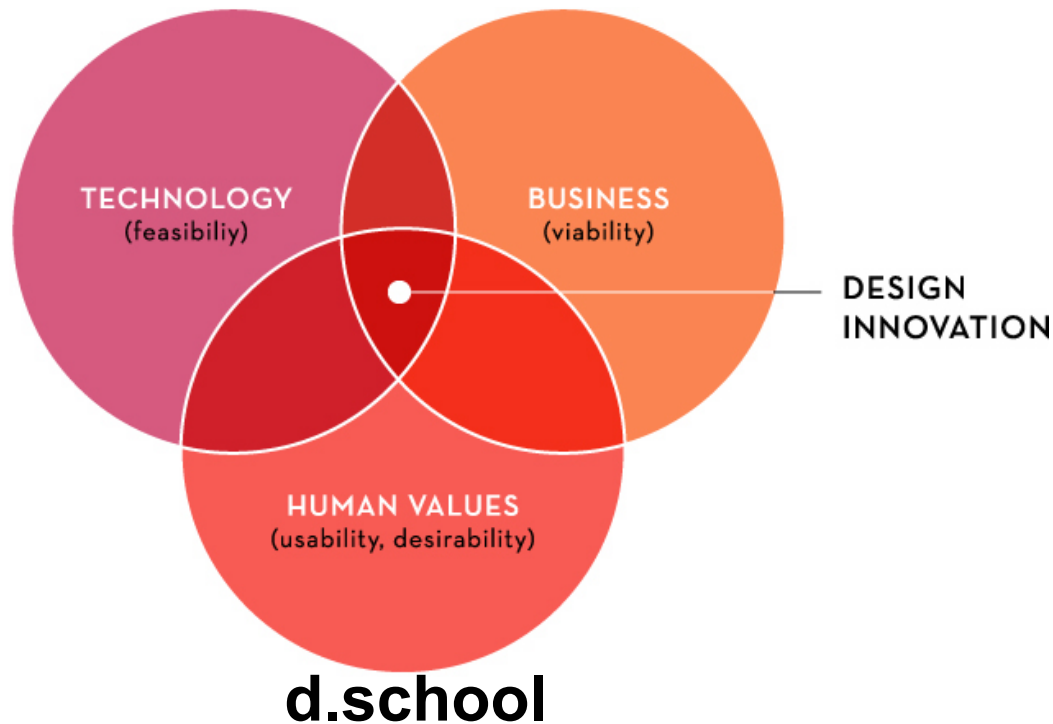


T-Shaped People



How do we teach students about the horizontal part?

Horizontal Part of T – Two Examples



STANFORD
TECHNOLOGY
VENTURES PROGRAM

**Creativity, innovation, thinking
“out of the box”, team based
design.**



**Entrepreneurship,
management, business**

Creativity and Innovation

- **Can you teach this? If so, how?**
- **You don't teach these skills through normal classroom experiences.**
- **The best approach is to give students open-ended problems with multiple solutions they haven't seen before.**
- **Student competitions are a very effective approach.**
- **Global Innovation Tournament – first run in 2007.**

Creativity and Innovation

“Imagine It”

The challenge - create value from a simple object, post-its

Global Innovation Tournament

> 12 Countries | > 50 Schools | > 1,500 Students from Around the World

The image shows a YouTube video player interface. The video title is "An Algae Bioreactor from Recycled Water Bottles" by user "mfischer1000". The video shows a man standing next to a large rack filled with many clear plastic water bottles, each containing a green liquid (algae). The video has 35,569 views and 38 ratings. The player includes a progress bar, volume control, and sharing options for MySpace, Facebook, and Twitter. The description mentions Michael Fischer from Stanford University and discusses the challenges of increasing consumable energy availability.

The image shows the "Global Innovation Tournament Submissions" page on YouTube. It features a grid of video thumbnails with titles like "I Am Clean Hydration - Stanford Global Innovation Tournament", "Bottled Express", "A brandnew way to express", "Flow of Donations", "Shower Bottle can lead to Successful Career", "The old bottle", "A Little Bottle Planet - Innovation 08", "Armadura de juguete", "We Want Peace", and "Global Innovation Tournament L.M.N.". Each video entry includes its duration, view count, and rating.

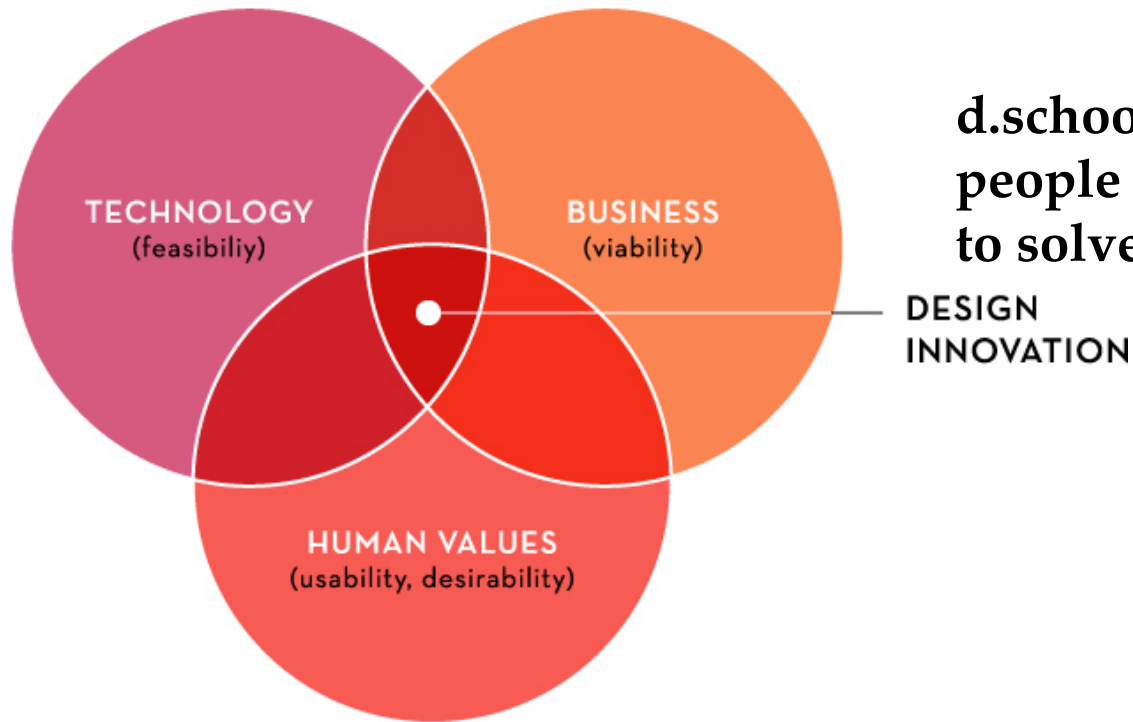
What would you do to create value from water bottles?

You can use as many water bottles as you like.

You have four days to complete the task.

Your presentation must be in the form of a video, 3 minutes or less.

Hasso Plattner Institute of Design



d.school : A place where people use design thinking to solve big problems

**DESIGN
INNOVATION**



Program Leadership

David Kelley

- **Professor of Mechanical Engr.**
- **Founder, former CEO and Chairman of IDEO, arguably one of the world's leading design firms.**

Hasso Plattner Institute of Design at Stanford



- Real projects
- Interdisciplinary teams
- Need-finding first
- Fail early and often but learn from failures



goal: students engaged and confident in their ability to innovate

d.light

10 student teams charged to help farmers in Myanmar improve their situation primarily through improving irrigation (water). 1 team discovered families have a lighting problem. Started a lighting company. Have since provided light to over 1 million people.

d.school Examples

Embrace

<http://embraceglobal.org/>

An innovative infant warmer that costs less than 1% of a traditional incubator.



Entrepreneurial Outlook

- **Entrepreneurship programs are springing up in many universities, sometimes in business schools, sometimes in engineering schools.**



STANFORD
TECHNOLOGY
VENTURES PROGRAM

- **Courses**
- **Seminars**
- **Student Competitions**
- **Summer internships in startups**

“Entrepreneurship is a mindset, an outlook that shapes the way you see the world and the possibilities that it holds. It is born of a basic dissatisfaction with the status quo, and it is the courage to say to yourself, “This could be better.”

Sample STVP Courses

- **Introduction to High Technology Entrepreneurship**
- **Management of Technology Ventures**
- **Global Entrepreneurial Marketing**
- **Strategy in Technology-Based Companies**
- **Technology Venture Formation**
- **Entrepreneurial Thought Leader Seminar**
- **Organizational Behavior and Management**
- **Entrepreneurial Finance**
- **Creativity and Innovation**
- **Negotiation**

Educating Scientists/Engineers For The 21st Century

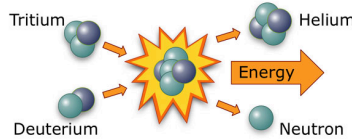
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NAE Grand Challenges For Engineering



**Make Solar Energy
Economical**



**Provide Energy
From Fusion**



**Develop Carbon
Sequestration methods**



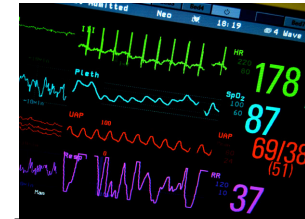
**Manage The
Nitrogen Cycle**



**Provide Access
To Clean Water**



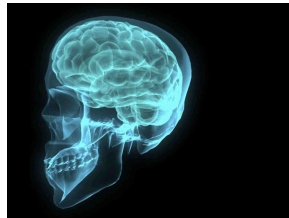
**Restore and Improve
Urban Infrastructure**



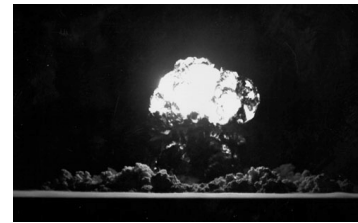
**Advance Health
Informatics**



**Engineer Better
Medicines**



**Reverse Engineer
The Brain**



**Prevent Nuclear
Terror**



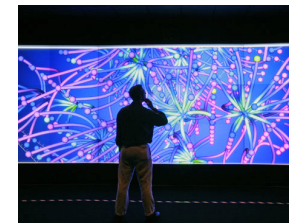
**Secure
Cyberspace**



**Enhance Virtual
Reality**



**Advance Personalized
Learning**



**Engineer The Tools²⁵
Of Scientific Discovery**

Interdisciplinary Research

- **Virtually all of the “Grand Challenges” are interdisciplinary.**
- **They will not be solved by individual faculty working in isolation.**
- **How do you incentivize faculty to work together?**
 - **New facilities that “change the rules”.**
 - **Research \$ to seed new collaborations.**
 - **Incremental faculty billets that “fill in the gaps”.**



Stanford Engineering Major initiatives

Information Technology

- Historically semiconductors, computers, software
- Going forward - internet based services, robotic vehicles, virtual worlds

Energy

- Solar, wind, fuel cells, “smart grid”, batteries

Environment

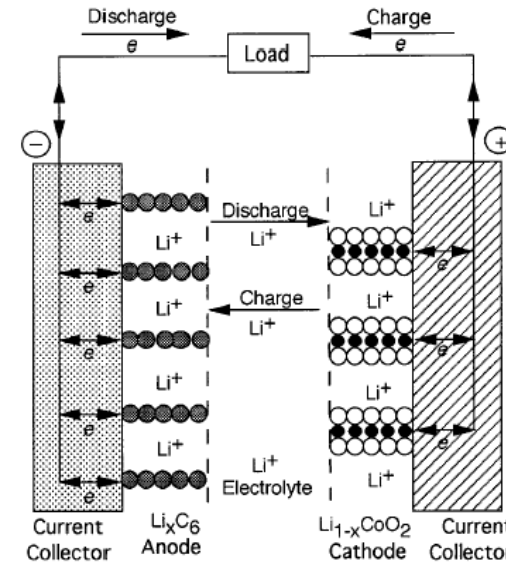
- Built environment, transportation systems, water resources

Human Health

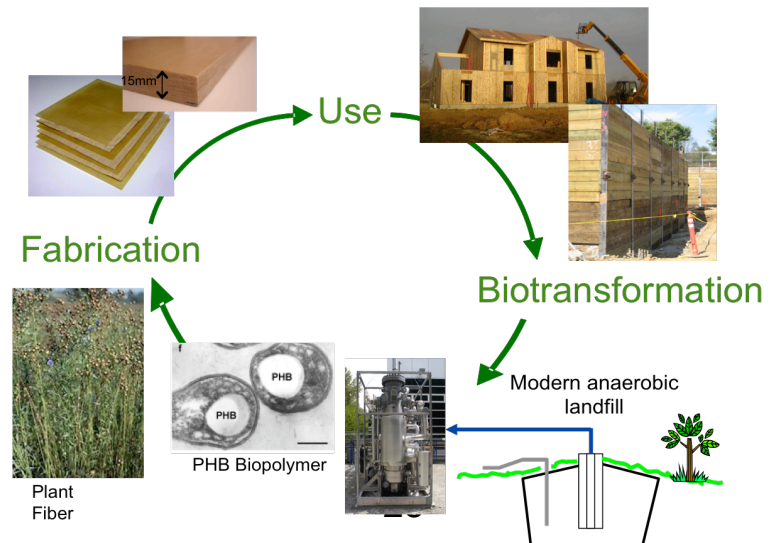
- Detecting disease early, new treatments, extending productive lifetimes

What Are Our Faculty and Students Working On?

- New anode materials for Li ion batteries - Si nanowires
- New “all electron” batteries
(2 new companies recently started)



- Artificial wood made by bacteria from methane
(new company recently started)

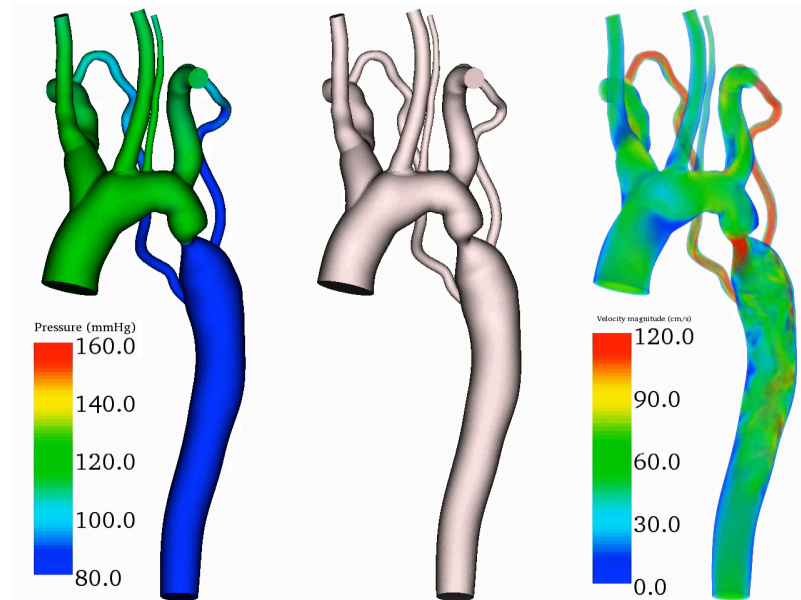


What Are Our Faculty and Students Working On?

- **Fully autonomous vehicles**
(Google launched a major program)



- **Simulation assisted surgery**
(new company recently started)

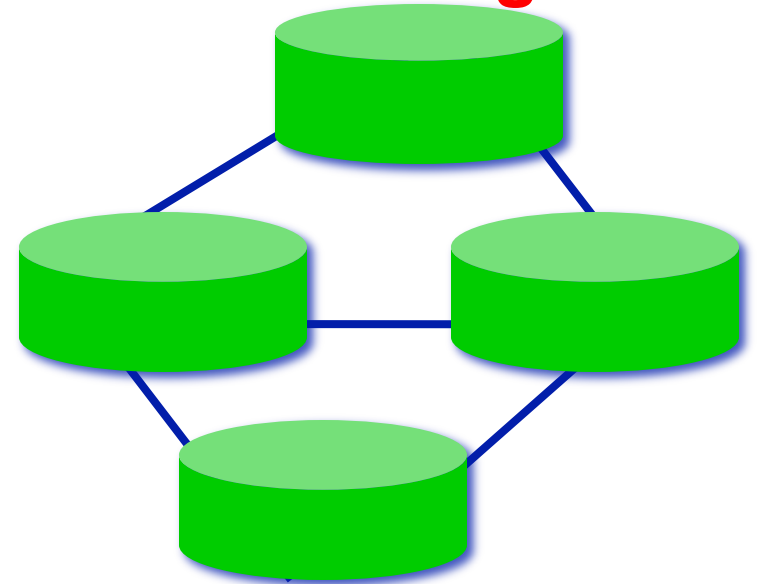


What Are Our Faculty and Students Working On?

- If we had a clean slate, how would we design the internet today?



- **Software-Defined Networking**
(new company recently started)



- **Could we supply most US energy needs from renewable sources?**

(several new companies recently started)



+ thousands of other projects

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History of Stanford Online

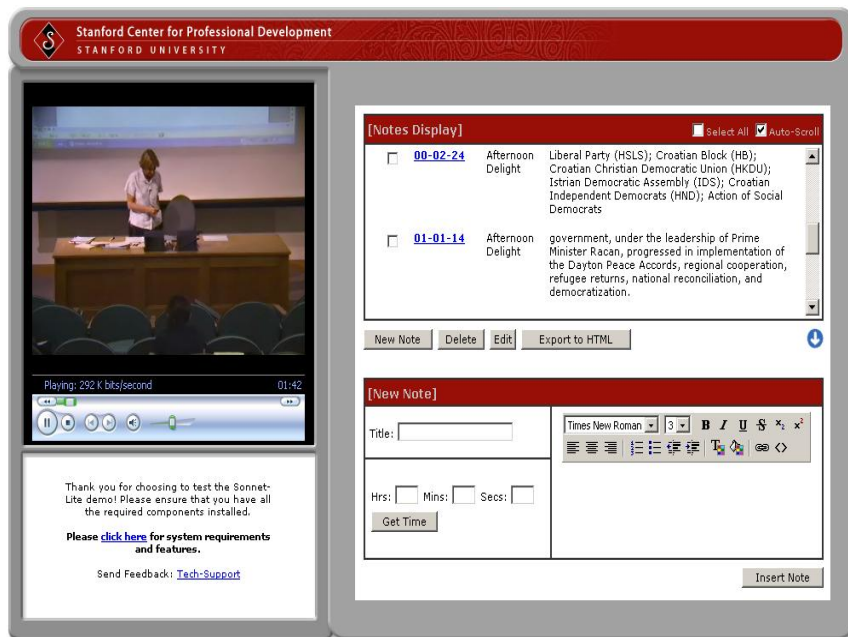
- **SCPD (started 40 years ago with TV broadcast)**
- **Stanford Engineering Everywhere (SEE)**
- **EPGY and Online High School**
- **iTunes U**
- **Stanford YouTube**

Online Education - Life-long Learning

**“We no longer want to hire engineers with a four-year degree. Instead we want our employees to have a 40 year degree” .
(Company CEO)**

“The ability to learn faster than your competitors may be the only sustainable competitive advantage”.

Peter Senge - “The Fifth Discipline”



- Online courses (some free)
- Free lecture notes
- 24/7 delivery

“Introduction to Databases” (Jennifer Widom)

CS145 @ Stanford

140 (enrolled students)

DB-Class @ world

60,000 (enrolled students)

26,000 (of them submitted 1+ assignments)

6,500 (completed the entire course)

DB-Class cumulative [April '12]

108,000 (accounts)

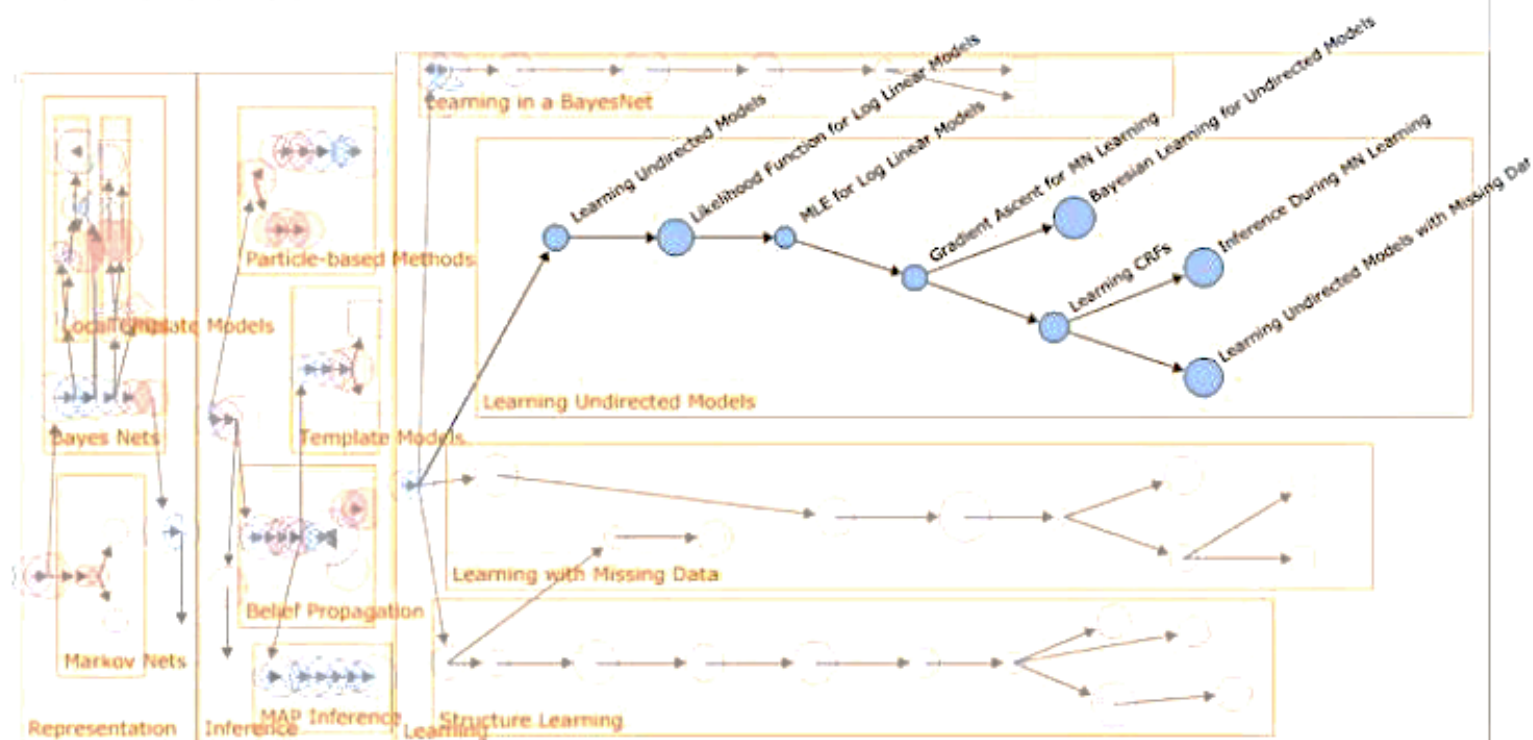
475,000 (assignment submissions)

3,150,000 (video views)

Graphical Concept Map

[View Text Version](#)

cs228 CONCEPT MAP



Zoom Out

Sample Video (lecture)

Transactions

Isolation Level Read Committed

- A transaction may not perform dirty reads
- Still does not guarantee global serializability

T_1 Update Student Set $GPA = (1.1) * GPA$ where $sizeHS > 2500$

concurrent with ...

T_2 Set Transaction Isolation Level Read Committed;
Select Avg(GPA) From Student;
Select Max(GPA) From Student;

$T_1 ; T_2$ $T_2 ; T_1$

A small video window in the bottom right corner of the slide, showing a woman with dark hair and a red top, likely the lecturer, speaking.

Previous video Next video 09:22/17:40 1.0x 1.2x 1.5x

Sample In-Video Quiz

Consider a relation $R(A,B,C)$ with multivalued dependency $A \twoheadrightarrow B$. Suppose there at least 3 different values for A, and each value of A is associated with at least 4 different B values and at least 5 different

What is

- ☒ 6
- ☐ 1
- ☐ 12
- ☐ 27

Explanation

Multivalued dependency $A \twoheadrightarrow B$ says that for each value of A, we must have every combination of B and C values. So for each of the 3 values of A we must have at least $4 \times 5 = 20$ different tuples.

OK

Correct

Show Explanation

Continue

Video player controls showing a progress bar, play/pause button, and speed controls (1.0x, 1.2x, 1.5x). The video title is "06:23/23:41".

Discussion Forum

- Students interact with each other & with staff
- Most questions answered within a few hours
- Some questions get > 100 views

Discussion

[Add New Question](#)

Double click to edit forum welcome message...

Popular Tags:

[FAQ \(4\)](#) [PA3-FAQ \(2\)](#) [PS2-FAQ \(4\)](#) [PS3-FAQ \(8\)](#) [bayesian networks \(2\)](#) [bug \(5\)](#) [chunk \(2\)](#) [courseware \(3\)](#) [hammersley-clifford \(1\)](#) [pa1 \(4\)](#) [pa2 \(13\)](#) [pa3 \(5\)](#)
[project \(2\)](#) [ps#1 \(4\)](#) [ps1 \(4\)](#) [ps2 \(11\)](#) [ps3 \(18\)](#) [quiz \(10\)](#) [submission \(1\)](#) [variable elimination \(2\)](#)

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37 views

Typo in quiz answer

For those who've watched this video before today (Wednesday 16/2), please note that the answer we provided for the in-video quiz was wrong. It has been changed accordingly, so do take another look. Thanks, and sorry for the error!

27 days ago · 0 posts · 0 likes · [Unread Question](#) · [Mark as read](#)

94 views

PS 2 q1f and legal MH samplers

1. What does it mean for an MH sampler to be 'legal'? Doesn't an MH sampler have to come along with some acceptance probability and then it may or may not sample from the correct posterior distribution? (question 2 removed by TA to avoid giving away solutions)

27 days ago · 0 posts · 0 likes · [Unread Question](#) · [Mark as read](#)

79 views

PS2, Q1c

Can anyone try to tell me what's going on here? The description doesn't really make any sense to me. What does our clique tree look like? Why are variables passing messages instead of cliques? I want to use Algorithm 13.2 and just take the log of $\psi(C_i)$, but I don't really see how everything fits together. I'm guessing

27 days ago · 0 posts · 0 likes · [Unread Question](#) · [Mark as read](#)

36 views

Question about lecture "Likelihood Functions for Log Linear Models"

Why is the answer to the in-lecture quiz not the one with the u -s summed out? Since it's just one parameter for all k values, then λ_{ij} is multiplied by the count of all cases where $(u_i=v_j)$, which is of course the complement of the cases in which $(u_i \neq v_j)$, which is a count over all possible assignments to u_i (and v_j).

27 days ago · 0 posts · 0 likes · [Unread Question](#) · [Mark as read](#)

114 views

Problem 1 part e unclear: what does $S_{i=j}$ actually mean?

The problem says Y is a 'set of observations', and implies that X is either a set of objects, or else a set of discrete values that may be taken by a property of an object. What, then, does the $S_{i=j}$ 'selector variable' mean? I think this might be clear to me if you explained more clearly what $\$X\$$ and $\$Y\$$ are? Thanks!

28 days ago · 0 posts · 0 likes · [Unread Question](#) · [Mark as read](#)

53 views

Block Log Distribution (PA2)

Is it possible to get an explanation for what we are trying to calculate in block log distribution?

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91 views

Observations format in PS2 q4

The question says that "the robot obtains a (noisy) measurement $O_{ij}(t)$ of its current position relative to each landmark i ." Is $O_{ij}(t)$ the (x, y) coordinate of landmark i on some coordinate system centered at the robot (and if so, does it depend on the direction the robot is moving), or is it just a one dimensional

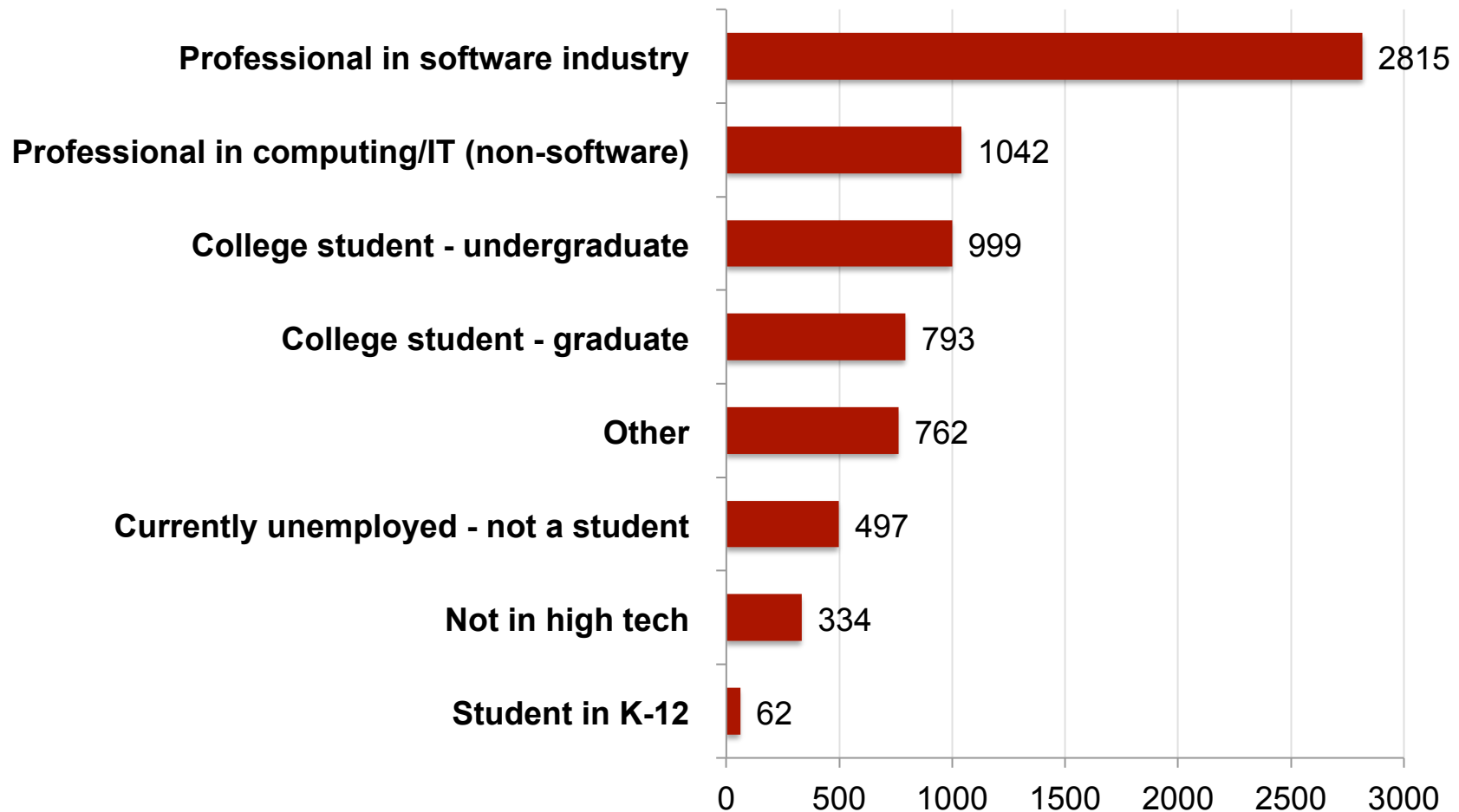
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Personal Touch



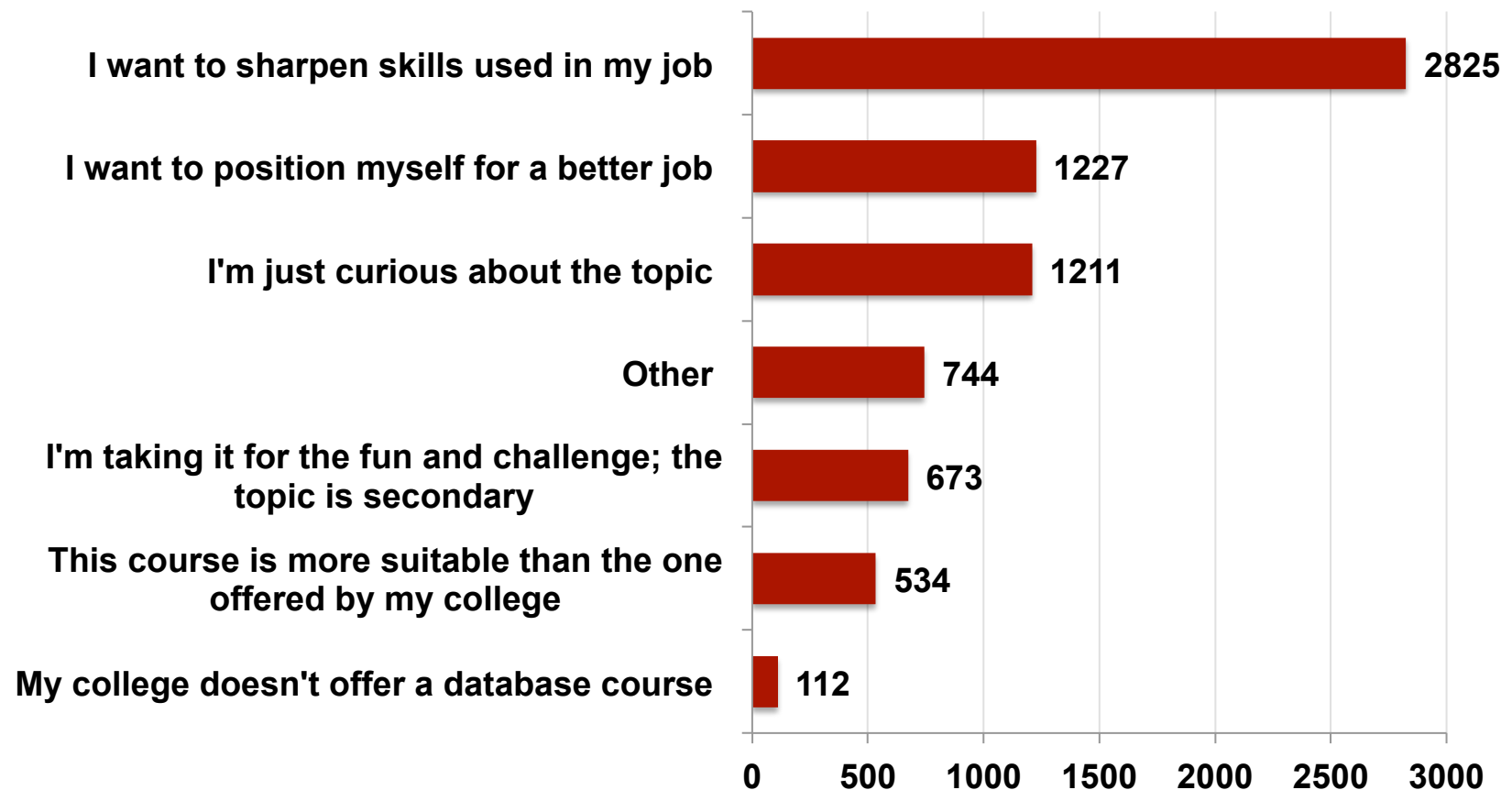
Student Survey

Who are you?



Student Survey

What is your primary reason for taking the class?



Meanwhile, back at Stanford . . .

Classroom Time (For On-campus students) The “Flipped Classroom”

- **Professor-led interactive problem-solving**
- **Lectures outside of core material**
 - **Guest lectures from industry**
 - **Guest lectures from Stanford**
 - **Research presentations**
 - **Advanced/exotic topics**
- **Help/review sessions**

Are We At An Inflection Point?

Why did experimental courses succeed?

Convergence of:

- **Video on demand**
- **Widespread connectivity**
- **Automated assessment and feedback***
- **Social media**
- **Semi-synchronous delivery**
- **Crowd sourcing***
- **Acknowledgement of completion**

*** Radically scalable mechanisms!**

Does Online Education Challenge Traditional Residential Education?

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- Elisabeth Rose

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Introduction to Sustainability
University of Illinois at Urbana-Champaign
Started 10 days ago (8 weeks long)



Networked Life
University of Pennsylvania
Starts in 5 days (10 weeks long)



A History of the World since 1300
Princeton University
Starts in 12 days (12 weeks long)



Introduction to Computational Finance and Financial Econometrics
University of Washington
Started 2 days ago (10 weeks long)

ACROSS 16 CATEGORIES

[View All 122 Courses >](#)

Biology & Life Sciences
Computer Science: Programming & Software Engineering
Economics & Finance
Health and Society & Medical Ethics
Mathematics
Statistics, Data Analysis, and Scientific Computing

Business & Management
Computer Science: Systems, Security, Networking
Education
Humanities and Social Sciences
Medicine

Computer Science: Artificial Intelligence, Robotics, Vision
Computer Science: Theory
Electrical and Materials Engineering
Information, Technology, and Design
Physical & Earth Sciences




FROM 16 UNIVERSITIES

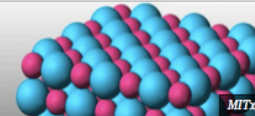


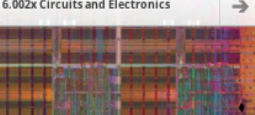


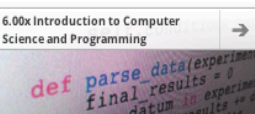
			
			
			
			

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6.00x Introduction to Computer Science and Programming  MITx		

Does Online Education Challenge Traditional Residential Education?

- If residential education is simply sitting in lecture halls taking courses, then the answer may well be YES.
- But a typical undergraduate residential education is much more than this.
- And a PhD education is much more than this.
- But MS degrees based purely on attending classes could be at risk, particularly if top tier universities “certify”.
- And junior colleges, community colleges could be affected.
- Residential programs may have to reinvent themselves to compete with low cost online programs.

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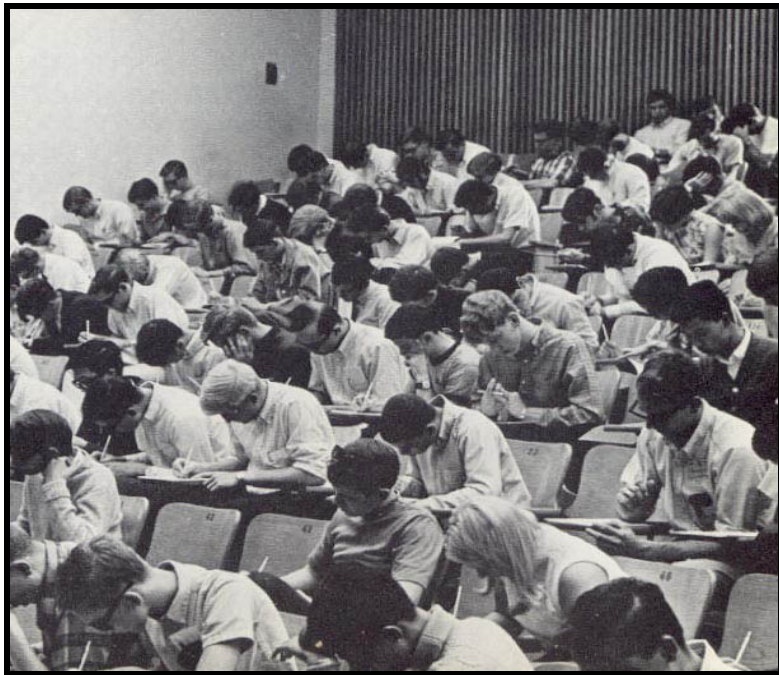
The world is changing, universities are changing, education is changing. We live in interesting times!

Educating Engineers/Scientists For The 21st Century

“Students are driven by passion, curiosity, engagement and dreams . . .”

“In the long run, making universities and engineering schools exciting creative, rigorous, demanding and empowering milieus, is more important than specifying curricular details”

Charles Vest - *Educating Engineers for 2020 and Beyond*



Thank You!

Questions?