

CLASS ELEVEN:

Improving the Talent Base – New Education and Training Models

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MIT – STS.081/17.395

Innovation Systems for Science,
Technology, Mfg., Energy and Health

Norman R. Augustine, Is America Falling Off the Flat Earth? (NAS 2007)

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“ U.S. Children Are Not Prepared for 21st Century Jobs:

“ According to a recent survey, 86% of US voters believe that the United States must increase the number of workers with a background in science and mathematics or America's ability to compete in the global economy will be diminished.

“ About one-third of the 4th graders and one-fifth of the 8th graders lacked the competence to perform even basic mathematical computations. Without these basic skills, these students will have trouble succeeding in the future American workforce.

“ US Children Being Taught by Teachers Not Trained in Math And Science ”

“ In 1999, 68% of US 8th-grade students received instruction from a mathematics teacher who did not hold a degree or certification in mathematics. ”

“ In 2000, 93% of students in grades 5–9 were taught physical science by a teacher lacking a major or certification in the physical sciences (chemistry, geology, general science, or physics) ”

“ U.S. children Are Falling Behind Their Foreign Counterparts ”

“ We can see the results of our de-emphasis on math and science education in our country and it has long-term, global implications. ”

“ In 1995 (the most recent data available), US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science. ”

“ US 15-year-olds ranked 24th out of 40 countries that participated in a 2003 Program for International Student Assessment (PISA) examination, which assessed students' ability to apply mathematical concepts to real-world problems. In 2006, American teenagers ranked 21st in science and 25th in math among 30 industrialized nations. ”

- “ *The US Secondary Educational System is not Preparing our Students for Math, Science or Engineering Majors and too Few Students end up majoring in disciplines for high-tech careers.* ”
- “ Faltering secondary education system: fewer than 15% of high school graduates have sufficient mathematics and science credentials to even begin pursuing an engineering degree, and 40% of four-year college students end up taking at least one remedial course. ”
- “ To keep up with a more competitive global environment, need more of our students majoring in math, science and engineering, otherwise Americans will be left behind. Yet, we are seeing the reverse trend. ”

Augustine, con't

“ Almost twice as many bachelor's degrees were awarded in physics the year before Sputnik, deemed a time of dangerous educational neglect, as 2007. And, the U.S. share of the global output of doctorates in science and engineering declined from 52% in 1986 to 22% in 2003.

“ The United States ranks 17th among developed nations in the proportion of college students receiving degrees in science or engineering, a fall from third place three decades ago. It ranks 26th in the proportion receiving undergraduate degrees in mathematics.

Augustine, Con't

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“ Some 34% of doctoral degrees in natural sciences (including the physical, biological, earth, ocean, and atmospheric sciences) and 56% of engineering PhDs in the United States are awarded to foreign-born students.

“ Yet, we are moving in the wrong direction. About one-third of US students intending to major in engineering switch majors before graduating. As a result, 38% of PhDs in the US science and technology workforce were foreign-born, as of 2000.

Prof. Paul M. Romer (Stanford, NYU),
“Should the Government Subsidize Supply
or Demand in the Market for Scientists and
Engineers?” Nat’l Bur. Of Eco. Res.,
Working Paper 7723 (6/2000)

“The Issue: Federal Gov’t subsidizes private sector *demand* (esp. tax incentives, R&D tax credit) for scientist/engineer talent

“ Doesn’t ask whether the *supply response* allows these subsidies to work

“Reality: Institutional arrangements in Univ’s limit this supply response

“So we need: new incentive system

Romer, Con't–Underlying Thesis:

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- “ 1) In the 20th Century, “rapid technological progress in the US drove the unprecedented growth in output and standards of living”
- “ 2) “fostered by publicly supported system of education that provided the essential input into the process of discovery and innovation – a steady flow of people trained in scientific method and in the state of the art in their area of specialization”
- “ YET: Public Policy has ignored the structure of our institutions of higher ed
- “ SO: gov't programs to speed up innovation rate is thwarted by that structure
- “ Gov't programs focused on the DEMAND (R&D tax credit) side not the SUPPLY side for this talent- wrong direction - inefficient

Romer - Thesis, Con't:

- “ Speeding up growth is the only way we'll be able to cope with the demographics revolution that is upon us – need at least .5% higher growth rate
- “ Conservative estimate of of the add'l return on R&D spending: 25% [this is low – over 50%]
- “ So increase R&D spending by 2% of GDP and, *voila!* We' re at +.5% GDP growth!
- “ BUT: to speed up growth “it is not enough to increase spending on on R&D”
- “ Instead – have to “increase the total quantity of inputs that go into the process of R&D”
- “ That Means: TALENT, the big input

Romer - Thesis, Con't:

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- “ A “basic insight of economics is that for the economy as a whole, things have to add up”
- “ “If the total number of scientists and engineers is fixed” then you limit your biggest input into innovation and thus growth – (basic idea behind Romer’s Prospector Theory)
- “ And: US is not expanding its supply of science and engineering talent –went way up from .3% to .8% of labor force (GI bill, Sputnik) but frozen since 60’s - growth drag (and wait until baby boom retires, when it will get worse)
- “ SO: despite increase of gov’t incentives on tax side to corps. (ie, demand subsidy), this is not resulting in growth of key input to innovation - talent

Romer, Con't – The Undergrad Supply Problem in Univ's:

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- “ If demand side incentives aren't working, what has broken down on the talent supply side?
- “ Univ. measures itself by ability to select top-SAT scoring students - not pressured to indicate what happens to them (ie, no salary info)
- “ Traditional liberal arts univ. faces little pressure to respond to shift in skills needs
- “ Univ. has fixed investment in faculty teaching outside sciences
- “ So: Internal pressure to maintain the relative size of dept's
- “ Univ Solution - Make it more difficult for students to get science degrees

Romer – Undergrad Problem, Con't :

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- “ Science faculty is happy to keep teaching loads down by keeping “professional standards” high– ie, lower grades
- “ Other non-science dept’s increase their attractiveness by grade inflation
- “ This is what is happening: 40-50% of students entering undergrad science/engineering programs shift to other areas
- “ Grade inflation is real in non-science, has not happened in sciences/engineering
- “ 1998 study: 80%+ A’s or B’s for History/English vs. 54% Math –
- “ Supply problem for undergrads affects grad student levels
- “ US industry tries to make shortfall up with foreign born science talent – starting to dominate US science and engineering PhD programs

Romer – The Univ PhD Problem:

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- “ In science PhD programs: supply growth, but trained for academia (in basic not applied research), yet there the number of faculty positions is frozen
- “ Result of zero academic demand: PhD training now 8 years, and “post doc” invented to allow huge surplus to hang around univ’s (medieval: apprentices for masters)
- “ Result: science PhD frustration
- “ Romer’s picture: “undergrad institutions that are a critical bottleneck in the training for scientists and engineers”
- “ AND “graduate schools that produce people trained only for employment in academic institutions as a side product of producing basic research results”
- “ “The challenge in this area is not to increase the total numbers of PhD recipients but to increase the fraction of them that can put their skills to work in private sector R&D”

Romer, Con't – Supply Goals:

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- “ Romer doesn't wring his hands like a typical economist “dark science” type, he actually proposes interesting fixes!
- “ **Goal:** Increase the fraction of 24 year old citizens with degrees in sci/engineering from 5.4% of 24 year olds to 10% by 2020
- “ **Goal:** Innovation in grad training programs in sci/engineering - training for private sector R&D
- “ **Goal:** redress the imbalance in federal incentives for demand AND supply and get the supply incentives right this time - \$1b

Romer, Con't – Supply Fixes:

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Fix #1: training grants to undergrad univ's that increase the numbers of students receiving sci/engineering degrees

“

Fix #2: objective achievement-based tests that show undergrad mastery of sci/engineering areas (break grading system)

“

Fix #3: new class of portable fellowships that pay \$20,000 for 3 years of grad training in sci/engineering – and fund a new type of degree that reflects this program

Richard B. Freeman, Does Globalization of the Sci/Eng. Workforce Threaten U.S. Economic Leadership? (6/05)

- “ US - 5% of world pop., but 1/3 of world sci/engineering researchers
- “ US comparative advantage - leadership in sci/tech
- “ US share of world S&E workforce declining
 - “ China: no PhD's in 1975; in '03, 13,000
 - “ China will produce more PhD's than US by 2010
 - “ Foreign born share of US Sci/Eng PhD's: 42%
- “ US has adequate supply of Sci/Eng talent only because of sci/eng immigrants from abroad

Freeman, Con't

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- “ Offshoring R&D - Major high tech firms are locating new R&D facilities in China and India
- “ As nos. of sci/eng's working in foreign countries increases, US comparative advantage in high tech sectors will decline
- “ What is good for other parts of the world is not inevitably good for the US

Freeman, summary

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“ This paper develops four propositions that show that changes in the global job market for science and engineering (S&E) workers are eroding US dominance in S&E, which diminishes comparative advantage in high tech production and creates problems for American industry and workers:

“ (1) The U.S. share of the world's science and engineering graduates is declining rapidly as European and Asian universities, particularly from China, have increased S&E degrees while US degree production has stagnated.

“ 2) The job market has worsened for young workers in S&E fields relative to many other high-level occupations, which discourages US students from going on in S&E, but which still has sufficient rewards to attract large immigrant flows, particularly from developing countries.

Freeman Summary, con't

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3) Populous low income countries such as China and India can compete with the US in high tech by having many S&E specialists although those workers are a small proportion of their work forces. This threatens to undo the "North-South" pattern of trade in which advanced countries dominate high tech while developing countries specialize in less skilled manufacturing.

“

4) Diminished comparative advantage in high-tech will create a long period of adjustment for US workers, of which the off-shoring of IT jobs to India, growth of high-tech production in China, and multinational R&D facilities in developing countries, are harbingers.

“

To ease the adjustment to a less dominant position in science and engineering, the US will have to develop new labor market and R&D policies that build on existing strengths and develop new ways of benefitting from scientific and technological advances in other countries.

Claudia Goldin & Lawrence
Katz (Harvard economists),
“The Future of Inequality:
(Milken Inst. Review July 2009)

- “ Gap between wages of educated and less well educated workers growing since 1980
- “ This expanding wage inequality has characterized US since that time
- “ But: wage inequality narrowed from 1910 into the 1950's - then was stable until the 1980's
- “ Why? Race between technological change and educated workforce

- “ Technology advance - key to growth
 - “ Requires ever-higher educational attainment
 - “ Have to be well- educated to realize the gains of technology advance
 - “ Ebb and flow of wage inequality is all about education and technology
- “ US economy grew rapidly in post-WW2-1973 period
 - “ 1947-1973: real income grew 2.6% - all quintiles
 - “ 1973-2005: bottom fifth of real income: no growth;
 - “ Top fifth 1.6% annual growth; top 5% 2% annual growth
 - “ In that 1973-2005 period: wage inequality tied to rising differences between wages of highly educated and less educated

- “ Average years of schooling increased rapidly and continuously for Americans born from 1875 to 1950
 - “ US led the world in universal education in the first half of the 20th century
 - “ Free compulsory education increased from grade school to high school; continued with mass higher education - a US first
- “ Efforts to reduce wage inequality depend on increasing the supply of educated workers
- “ US economy grew rapidly through technology advance, with wages growing in tandem to growing education attainment 1910 through 1973
 - “ US led way in mass secondary then mass higher ed
 - “ Educational attainment increased almost 1 year per decade from 1875 to 1950
- “ But then attainment stagnated in 1970s – plateau-ed
 - “ Sharp slowdown in rise in high school and college grad

- “ College grads continue to command a wage premium - strong growth since 1950
 - “ Relative supply of college-educated workers increased at annual rate of 3.8% from 1960-80, but at just 2% from 1980-2005
 - “ The soaring wage premium for college-educated workers is driven by the supply shift
- “ **Starting 1973 (and esp. 1980s) growing wage inequality - parallels two factors: rising technology advance and stagnating ed attainment for bottom 3/5' s of wage earners**
- “ **Want to restore widespread wage mobility? Revitalize education attainment - and spread gains of tech advance through society again, not just top tier**

**Prof. William J. Baumol, NYU,
“Education for Innovation:
Entrepreneurial Breakthroughs
vs. Corporate Incremental
Improvements,” Nat’l Bur. Eco.
Research, Working Paper (April
30 2004)**

“Thesis:

- “ Breakthrough innovation comes from independent inventors and entrepreneurs**
- “ Large firms concentrate on incremental innovation**
- “ Education for mastery of science knowledge aids incremental advance not breakthroughs**

Baumol - Thesis, Con't:

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- “ Standard science education may impede breakthrough thinking and imagination
- “ Large firm R&D requires scientists & engineers educated in extant info and analytic methods
- “ Successful inventors and entrepreneurs often lack such standard preparation
- “ Procedures for incremental learning seem to work – but we don't know how to educate for innovation

Baumol, Con' t- Talent Examples:

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- “ Proctor & Gamble – 7500 scientists, 1250 PhD’ s, more than the Harvard, Stanford, MIT faculties, 22 research centers, 12 countries --- VERSES:
- “ Watt, Eli Whitney, Fulton, Morse, Edison, the Wright Bros., Wozniak, Jobs, Gates & Dell – no college degrees, little sci. training
- “ *Education where you master the received body of knowledge may be a hindrance to invention, innovation*

Baumol, Con't – Contrast in Small/Large Company Roles

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- “ Progress requires both breakthrough ideas and protracted follow-up process of cumulative incremental improvement of breakthroughs
- “ Industrial labs ill-suited to breakthroughs but well-designed for the incremental tasks
- “ Sharp differentiation between economic contributions of entrepreneurs/inventors contributing novel technologies and large firms providing improvements
- “ 70% of US R&D (ie, D) is private sector, and that means large firms and thus incremental
- “ Most revolutionary new ideas of last 200 years provided by independent entrepreneurs – see SBA surveys

Baumol, Con't - 7 Hypotheses:

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- “ 1) Disproportionate share of breakthroughs from independent inventors/entrepreneurs, large firms do incremental
- “ 2) Large proportion of startups involve former ee's of large firms – leave because large firm unreceptive to novel ideas, or little reward for novel ideas
- “ 3) Training for mastery of available sci/tech data is of great value for innovation and growth; but education for original thinking and imagination also crucial to growth

Baumol - 7 Hypotheses, Con't:

- “ 4) Education for incremental advance different from education for novel advance
- “ 5) R&D divisions of large firms require personnel with training in extant sci/tech info and extant analytical methods; this kind of education may hinder the independent entrepreneur/ inventor
- “ 6) Incremental improvement may require far more mastery of demanding sci/tech info than original novel idea
- “ Example – think of the airplane the Wright Bros. built vs. what a Boeing 787 is like

Baumol – 7 Hypotheses, Con't:

“ While both educational approaches may be very different, neither is inferior to the other – need both – both essential for innovation and growth

“ Problem:

“ We seem to have down education for acquiring extant sci/tech info – BUT:

“ How do you educate for original and novel idea generation?

“ American Education seems to be less demanding and rigid than other industrialized countries, hence some innovation success? – but what are the key features?

**Bonvillian & Weiss,
Legacy Sectors book - The
Online Challenge to
Higher Education - 2015**

“ Opening Q’s:

“ Will MOOCs be a disruptive innovation and disrupt higher ed substituting a new model?

“ Will higher ed respond with a ‘Blended Model’ or just ignore this?

Bonvillian and Weiss, con't

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“ Univ.’s are deep problem for this disruptive innovation: **Universities are Legacy Sectors**

“ Resist disruptive change

“ Conduct almost no R&D on education – innovation averse

“ Perverse pricing issue

“ Very decentralized – hard to spread learning – collective action problem

MOOC Providers in the U.S.:



- Non-Profit – <https://www.edx.org/how-it-works>
- First course: 200,000 students world wide; most were shoppers – but 8% completed for certificate –
 - more students than at MIT
 - edX numbers 10 million of students worldwide
- Many more courses now so fewer per course – with some training exceptions
- Non-profit – so participants control their content and student data
- Courses are free
 - Charge for certificates



“ Students cooperate, assist each other, organize online discussion groups – optimal education

“ 60+ universities in consortium – MIT, Harvard, Berkeley, Univ. of Texas, Georgetown, UWash, Stanford, 12 Int’l Univ.’s., etc.–

“ the univ’s provide courses, edX is the “theatre” – technical support, course distribution

“ **OPEN SOURCE** technology platform

“ All platform technology posted and open

“ anyone can create a course through mooc.org

“ But what is the business model?

“ Course Development very expensive
MIT or edX may have to add a “Pixar”



For Profit:

Other MOOC providers:

coursera – former Stanford faculty – VC funding - 62 universities/colleges offer at least 1 course

-- Former Stanford faculty, VC funding --

Udacity/GaTech ex: - new Master's in computer science with GaTech with funding from AT&T - \$134 per credit vs. normal \$472 in state and \$1139 out of state – income split 60/40 between

-- **Univ. of Phoenix** – enrollment in 2012 – 308,000

-- **Kaplan** – enrollment in 2012 – 78,000

-- **Blackboard, publishers** entering the field



College prep STEM courses –Non-Profit

Are MOOCs “New Magic”?

“ Politicians – think this is IT “new magic”

“ Free, online higher education!

“ Right: We can get rid of pesky left-wing universities with a low cost for-profit model!

“ Left: We can get rid of outrageous tuition – drive tuition through the floor - make higher education low cost, and more accessible than ever before!

“ States passing laws requiring \$10,000 BAs

“ California – requiring state univ’s to give credit where not enough student seats

But...

**“What will
happen to --
Residential
Campus
Education?”**

What Online Ed Can Do

“ Online learning can support an education shift – new tool:

“ Tool for visualization, representation, reinforcement and assessment.

“ Using feedback loops and repetition tied to continuous assessment, online can convey information and content, reinforcing both.

“ Online will have features better than lectures and could force interactive classrooms and restructuring of face-to-face learning.

What Online Ed Can't Do

“ Vital education components remain face-to-face:

“ development of oral expression, presentation and advocacy skills and organizing expertise.

“ Written analysis currently requires human assessment except for straightforward assignments.

“ Research, central to learning-by-doing in science, remains face-to-face, although online features can enhance it.

What Remains **Face-to-Face**:

- The social features of exchanges in classroom and seminar build student involvement in learning
- interactive online features still can't fully substitute for **face-to-face intensity**.
- **Learning requires human scaffolding –**
 - “ for discourse,
 - “ for argumentation,
 - “ for mentoring,
 - “ for making the case,
 - “ for research,
 - “ for making the conceptual leap.

Blended Learning

- “ It will be the “human-machine symbiosis”
- “ Machines will do what they are good at – content, information
- “ Teachers will do what only they can do – mentoring, directing discussion, pushing expression of expertise
- “ Blended learning needs to prevail
- “ Will it?

BUT: The Technology will **Change**

“ Online technology’s interactive social and evaluation *features will evolve*

“ Can build online discussion groups

“ Still: not personal competition, intensity

“ Machine writing evaluation – getting better at edX–
best: word use, rubrics, core concepts – same grade
a teacher grader 85% of the time

“ Research can be complemented by online
simulation and modeling = HANDS ON LEARNING
TECHNOLOGY

“ i-Lab – access to actual adv’d lab

“ DOD: join personal tutors and MOOCs

“ Boundaries between online and face-to-face will
shift if we join it with the learning science.

Will Online Ed Disrupt Universities?

- “ Will universities go the way of publishers, newspapers, broadcast journalism? ”
- “ If universities disappear: **no course content** ”
- “ Universities are **research engines** as well as teaching and learning centers ”
- “ In a **knowledge economy**, **no substitute** for universities –they are the knowledge economy ”
- “ The university has become central to the way we organize an innovative society ”
- “ No real replacement – ”
- “ Students need learning mentors – **univ’s last if they upgrade face-to-face education** ”

The Online Revolution is Coming → Need to Figure out this New Tool – can't ignore it...

“ Need to bring Learning Science to Online Ed

“ MOOCs have been led by Computer Geeks not learning experts

“ But there is a parallel revolution now in learning

“ Undergraduates face learning challenges in

“ conceptual understanding,

“ visual representation and

“ problem solving

“ Instructional strategies emerging for each

Worldwide Online Education Revolution

- “ *Worldwide availability of courses* ”
- “ No limits in education reach – unprecedented – world learning revolution at hand ”
- “ Can reach low income learners everywhere ”
- “ Much broader impact – worldwide ”
- “ edX collaboration models – San Jose State, community colleges + edX content with classroom context ”
- “ Univ. much larger than the way it now sees itself; ”
- “ MIT doesn't have to be 10,000 students on campus between ages of 18-28 ”

Credentials/certificates/degrees

- “ *Business model: only works for online if offering certificates or degrees* ”
- “ Issues in accepting MOOCs for course credit – measures content acquisition but not expertise presentation or written expression ”
- “ Credentials/certificates – online content is still worthwhile – may want to measure and award these ”
- “ Employers may be interested in “stacks” of online credentials ”
- “ U.S. Community Colleges: already 40% certificates for professional skills ”

Throughput and Admissions

“ Perhaps students come to college with a year of intro courses completed on line?

“ But freshman year – important socialization

“ College costs – univ’s have the same fixed plant – grow utilization - quarterly system, attend 3 quarters?

“ Make college 3 years? **Increase Throughput**

“ **Admissions** – perhaps schools accept students based on performance in completing the first year of course?

Role in Lifelong Learning

Lifelong Learning may be best app:

“After you have the oral and written expression skills, online courses may fill a great need – a new way to update and improve your content knowledge and skills

“adult learning is increasingly content and information based

“Online may be critical for adult learning – for skills updates

“When you apply to college do you apply for lifelong content learning?

What is the Business Model?

“ MOOCs – very expensive up front to develop quality courses with interactive features - but potentially disperse these costs over a much wider group of students;

“ The courses can be freely available, but if you want a certificate, assessment needed and modest charge – but at what level? - differential pricing?

“ Blockbuster courses, faculty – premium charge?

“ How to charge for lifelong learning?

“ If one univ. develops a course, and another uses it in a blended model, what charge?

“ Are MOOCs copyrighted materials – who owns?

-->Overall – *very different business model for very different cost structure*

The Risk we need
to Understand

- “ Some universities as we know them now may close
- “ If lecture-based and no research base
- “ Online-only is not perfect, but it's going to be pretty good
- “ Univ's facing transformation - reflect a new blended model – new faculty role
- “ **ISSUE:** two higher education systems – face-to-face and online?
- “ With online, how will higher ed shift in Open access to global knowledge?

Bonvillian and Weiss - Wrap-Up:

- “ Much to **learn about learning**
- “ In the classroom,
- “ In blended learning, and
- “ In fully online environments
- “ Key –
- “ How to optimize learning in each environment so each does what it does best
- “ *Then* coordinate the three rings of the circus
- “ Note: If meaningful **learning analytics can be applied to growing online data mountains**, we could fill in gaps in our understanding of learning science

Bonvillain and Weiss - Wrap-Up - Continued

- The learning revolution (for the foreseeable future) will be *blended*
 - “ both online and face-to-face.
 - “ It's the *human-online symbiosis*
 - “ It's *Deep Blue and Gary Kaparov*
 - “ – the right blend of *students, teachers and teams with online capabilities*, all informed by advances in learning science –
 - “ *This* can be the enabler for a new generation of science learning.
 - “ Linking learning science to online will drive learning reforms in both physical and virtual spaces.
 - “ *ISSUE: Will Univ's just launch a few MOOCs and ignore the real opportunity: Blended?*

**MIT, Online Education
as a Catalyst for
Higher Education
Reform (4/1/16)**

“ Authors: Sarma, Willcox,
Klopfer, Lippel

“ Four Key
Recommendations:

“ 1) integrate learning
science from education
with cognitive
psychology and
neuroscience research

“ 2) optimally structured
online courses/modules
can be an important
facilitator in higher ed

MIT Online Ed
Report: Lessons from
Learning Science and
Brain and Cog

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- “ 4 examples re:
Recommendations 1 and 2:
- “ Mind Wandering
- “ Segment Learning into
bite-sized pieces
- “ Retrieval learning =
study/test, vs. study/study
- “ Spaced retrieval
- “ Role of curiosity

4 Examples re: Recommendations 1 and 2 (from Prof. Sanjay Sarma, Director of MITx): Mind Wandering is Natural

Mind Wandering is
Natural

Singer, Jerome L. *Daydreaming: An introduction to the experimental study of inner experience*. New York: Random House, 1966.

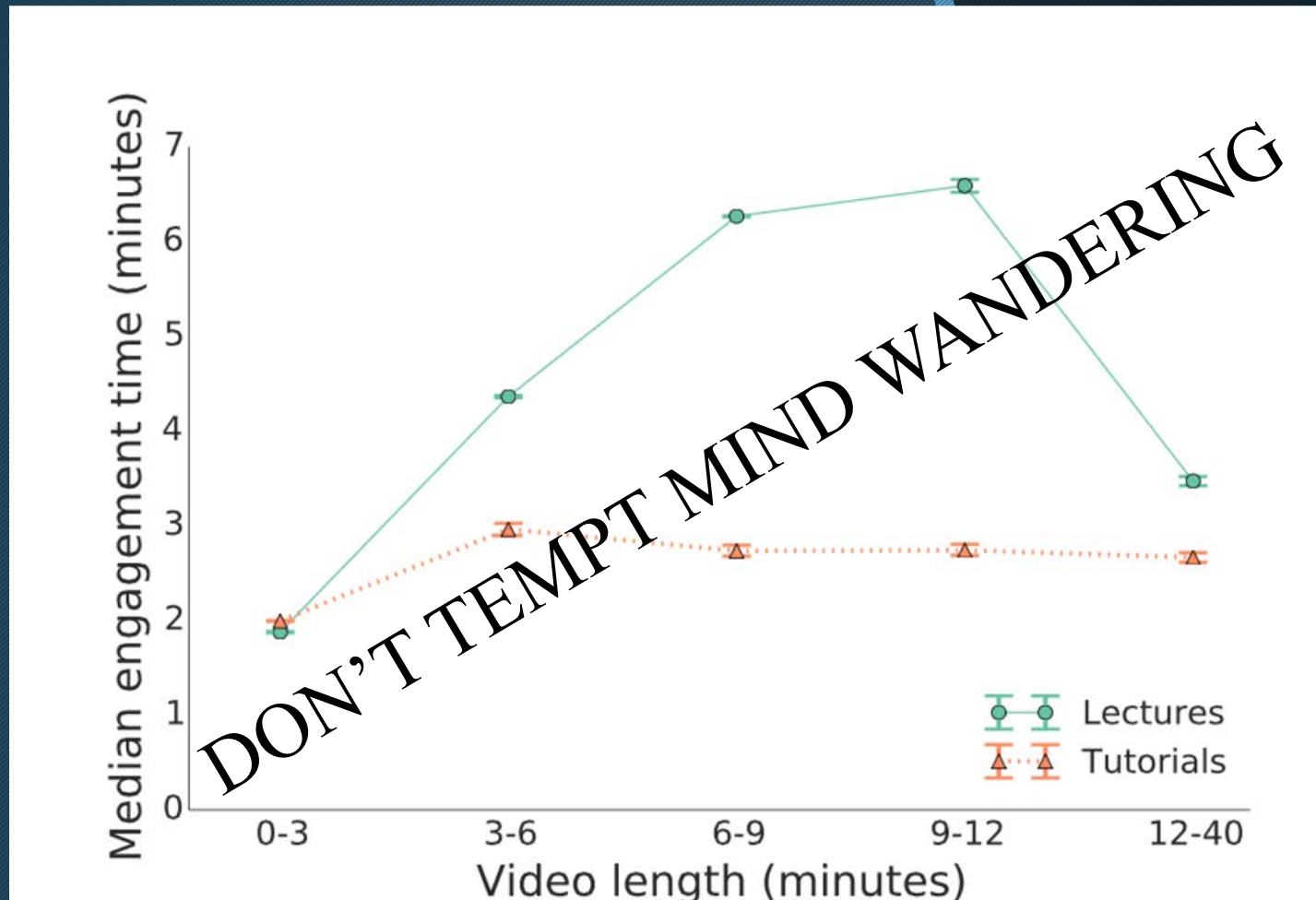
Mason, Malia F., et al. "Wandering minds: the default network and stimulus-independent thought." *Science* 315.5810 (2007): 393-395.

Christoff, Kalina, Justin M. Ream, and John DE Gabrieli. "Neural basis of spontaneous thought processes." *Cortex* 40.4 (2004): 623-630.

Baird, Benjamin, et al. "Inspired by distraction mind wandering facilitates creative incubation." *Psychological Science* (2012): 0956797612446024.

-> Segment learning into bite-sized chunks --

Lesson #1 for Learning



Guo, Philip J., Juho Kim, and Rob Rubin. "How video production affects student engagement: An empirical study of mooc videos." *Proceedings of the first ACM conference on Learning@ scale conference*. ACM, 2014.

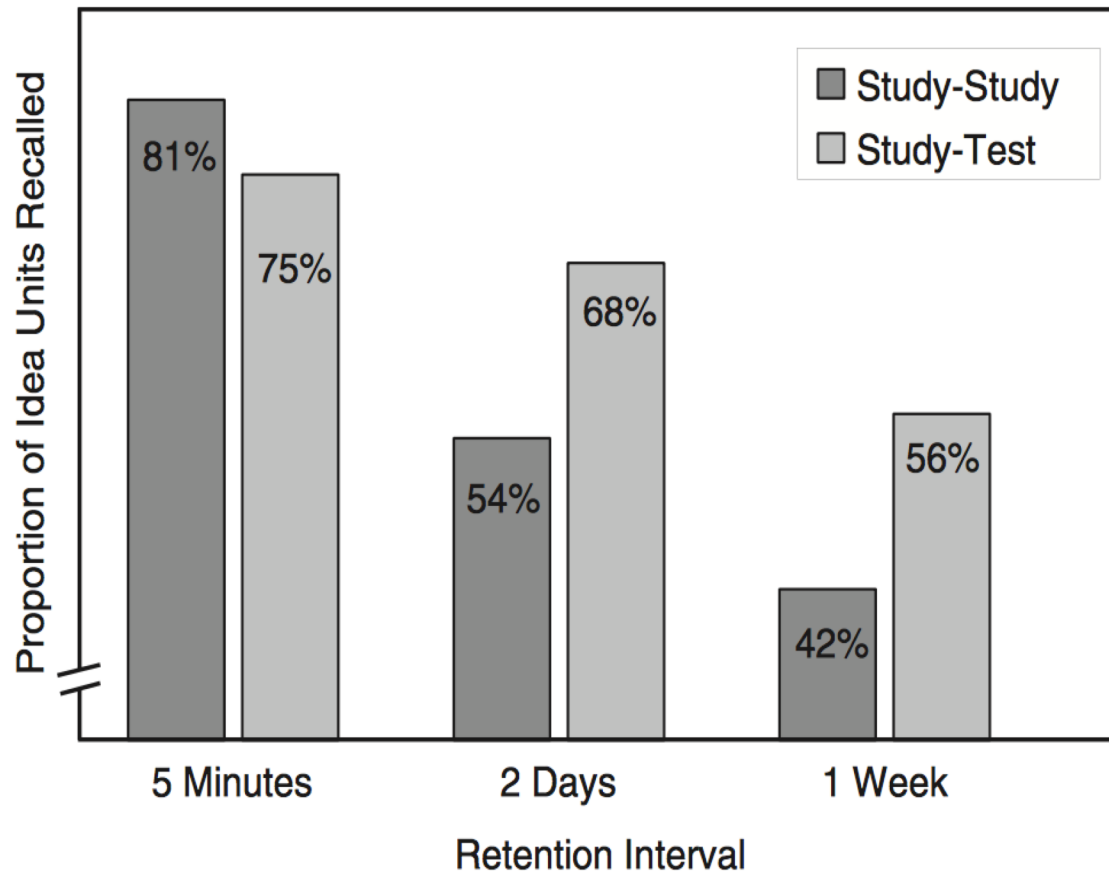
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Retrieval Learning

Lesson #2 for Learning



Karpicke, Jeffrey D., and Henry L. Roediger. "The critical importance of retrieval for learning." *Science* 319.5865 (2008): 966-968.

Roediger, Henry L., and Jeffrey D. Karpicke. "The power of testing memory: Basic research and implications for educational practice." *Perspectives on Psychological Science* 1.3 (2006): 181-210.

Lesson #3 Curiosity makes a difference -- Spaced Retrieval

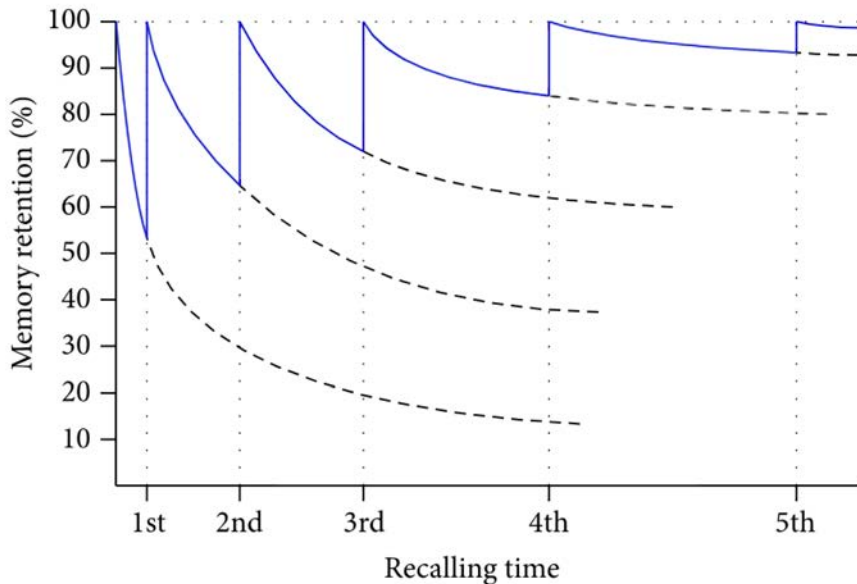


Figure 1: Ebbinghaus forgetting curve.

Image courtesy of [Yanhuang Jing et al.](#) Used under CC-BY.

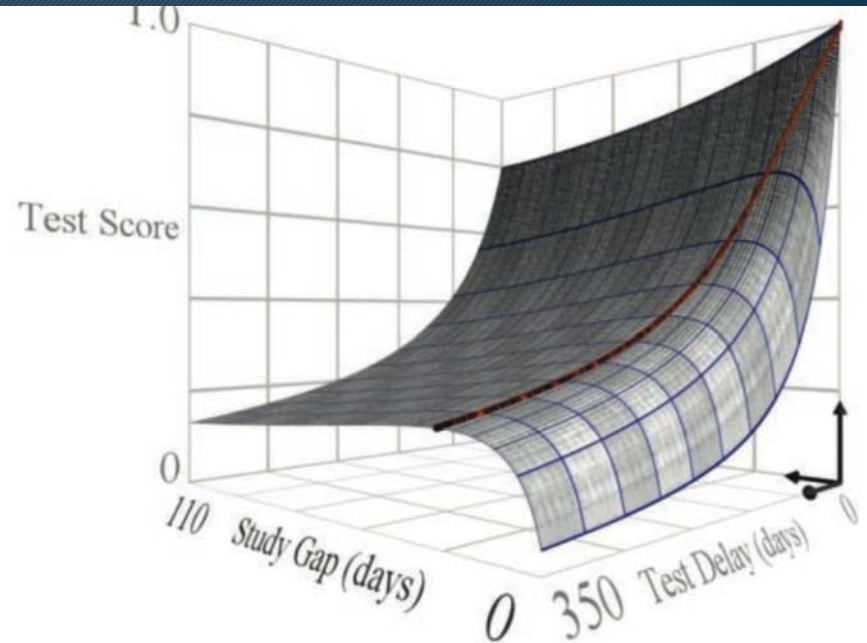


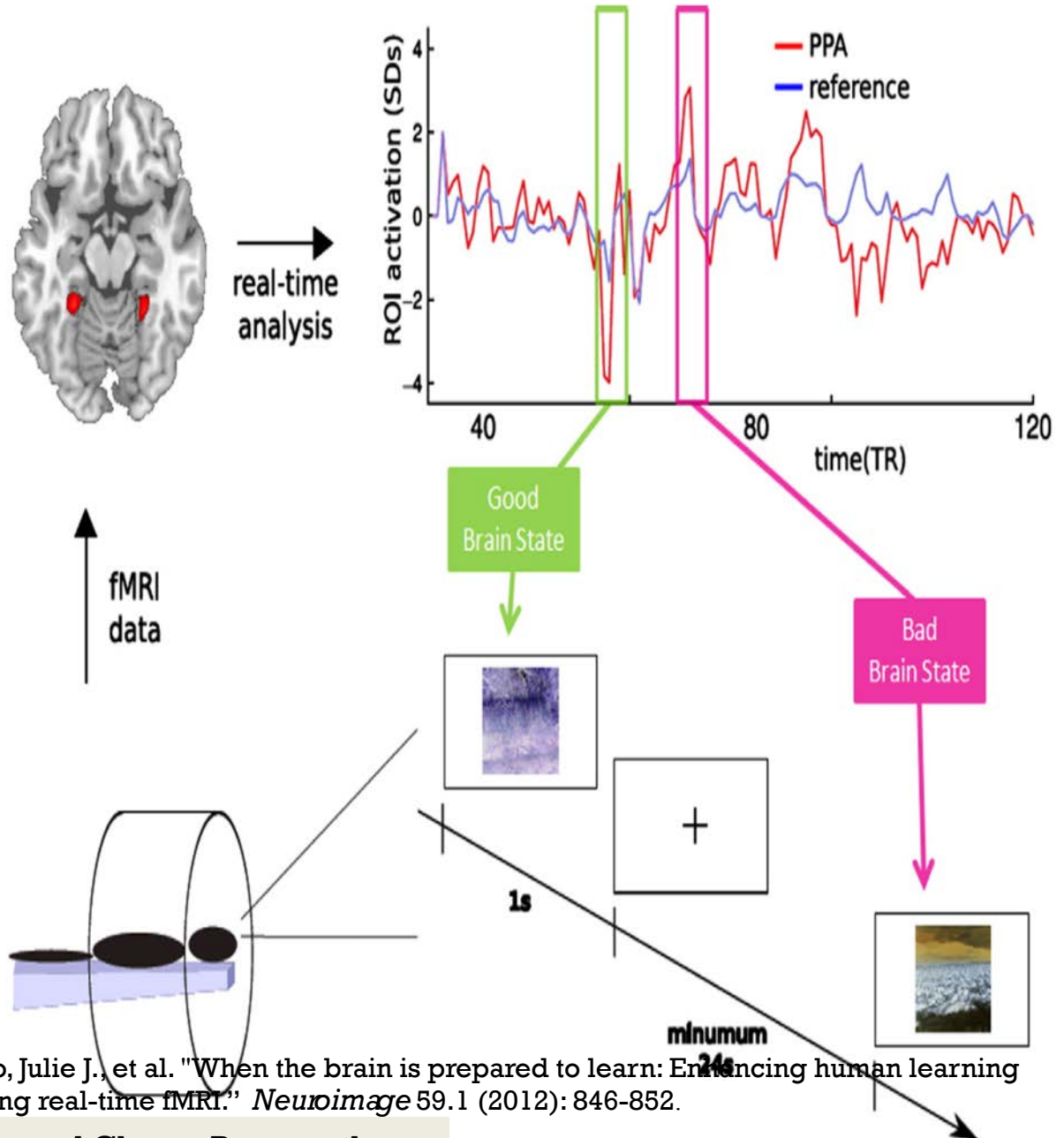
Image © [AERA](#). All rights reserved. This content is excluded from our Creative Commons license. For more information, see <https://ocw.mit.edu/help/faq-fair-use>

Cepeda, Nicholas J., et al.
"Distributed practice in verbal recall tasks: A review and quantitative synthesis."
Psychological bulletin 132.3
(2006): 354.

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<https://courses.p2pu.org/en/groups/studying-psychology-the-p2pu-way/content/task-21-the-ebbinghaus-forgetting-curve/>

Lesson #4: Curiosity makes a huge difference



Yoo, Julie J., et al. "When the brain is prepared to learn: Enhancing human learning using real-time fMRI." *Neuroimage* 59.1 (2012): 846-852.

Gruber, Matthias J., Bernard D. Gelman, and Charan Ranganath. "States of Curiosity Modulate Hippocampus-Dependent Learning via the Dopaminergic Circuit." *Neuron* 84.2 (2014): 486-496.

Image courtesy of Elsevier, Inc., <https://www.sciencedirect.com>. Used with permission. Slide courtesy of Sanjay Sarma. Used with permission.

- “ Recommendations, con't:
- “ 3) Support the expanding profession of “Learning Engineer” – way to work with faculty on online and blended course design using learning science –
- “ 4) Change model within higher ed Legacy Sector
- “ Need innovations online but who can be the change agents, institutions, groups?

Course Wrap-Up:

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“ **CLASS 1: Direct Innovation Factors: R&D (Solow) and Talent (Romer)**

“ Indirect Factors - ecosystem

“ **CLASS 2: Innovation Systems**

“ Look at innovation actors - Nelson

“ Culture

“ 3rd Direct Innovation Factor?

“ Organization of the Innovation System

“ Pipeline system: technology push - Vannevar Bush -radical/ breakthrough innovation - strong federal role

“ Induced innovation - industry led - tech pull - incremental advance

“ Innovation organization - the third key - aligning the innovation actors

“ **CLASS 3&4 – Mfg. as a case study - link between innovation/production**

“ **CLASS 5: Innovation at the Institutional Level**

“ How does the R and D and Prototyping handoff occur?

“ US system - V. Bush split R and D

“ Basic Research was federal science agency task; industry had the later stages

“ **CLASS 6: Result: Valley of Death between R and D**

Class Wrap-Up, Con't --

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“CLASS 7: Innovation at the Face to Face Level

“ People innovate not institutions

“ “Great Group” theory

“CLASS 8: DARPA: the connected science model

“ Breakthrough science to prototype stage

“ Bridges Valley of Death - right/left translational model

“CLASS 9: The NIH story: case study in institutional organizational problems

“ Basic research only, so valley of death problem

“ Stovepipes prevent cross-cutting tech advance

“ Industry issues: organized for blockbusters not for small disease populations diseases, infectious disease, or 3rd world disease

“ Biothreat model - create incentives for counter-market

“CLASS 10: Energy Technology:

“ The challenge of innovation within an established, complex Legacy sector

“ Have to look at Front End and Back End of innovation system

“ Fill gaps in innovation institutions

Class Wrap-up, Con't

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“

CLASS 11: Education

“

Freeman: talent base will affect innovation performance/growth

“

Romer point: Gov' t policy focused on capital supply and R&D incentives

“

Missing focus on inputs to R&D: talent - proof: GI Bill and Sputnik multiplied science talent base

“

Could turn around the number of college grads studying science/math and solve problem

“

Katz and Goldin: tech advance/education disconnect = income inequality

“

Bamol: educating for incremental advance not breakthrough advance - how do you educate for the latter?

“

MIT Online Ed Report –merge research, learning engineers, change agents

“

Bonvillian/Weiss – online ed offers rev in learning – blended reforms

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Manufacturing and Health
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