As We Train The AI, So The AI Can Train Us

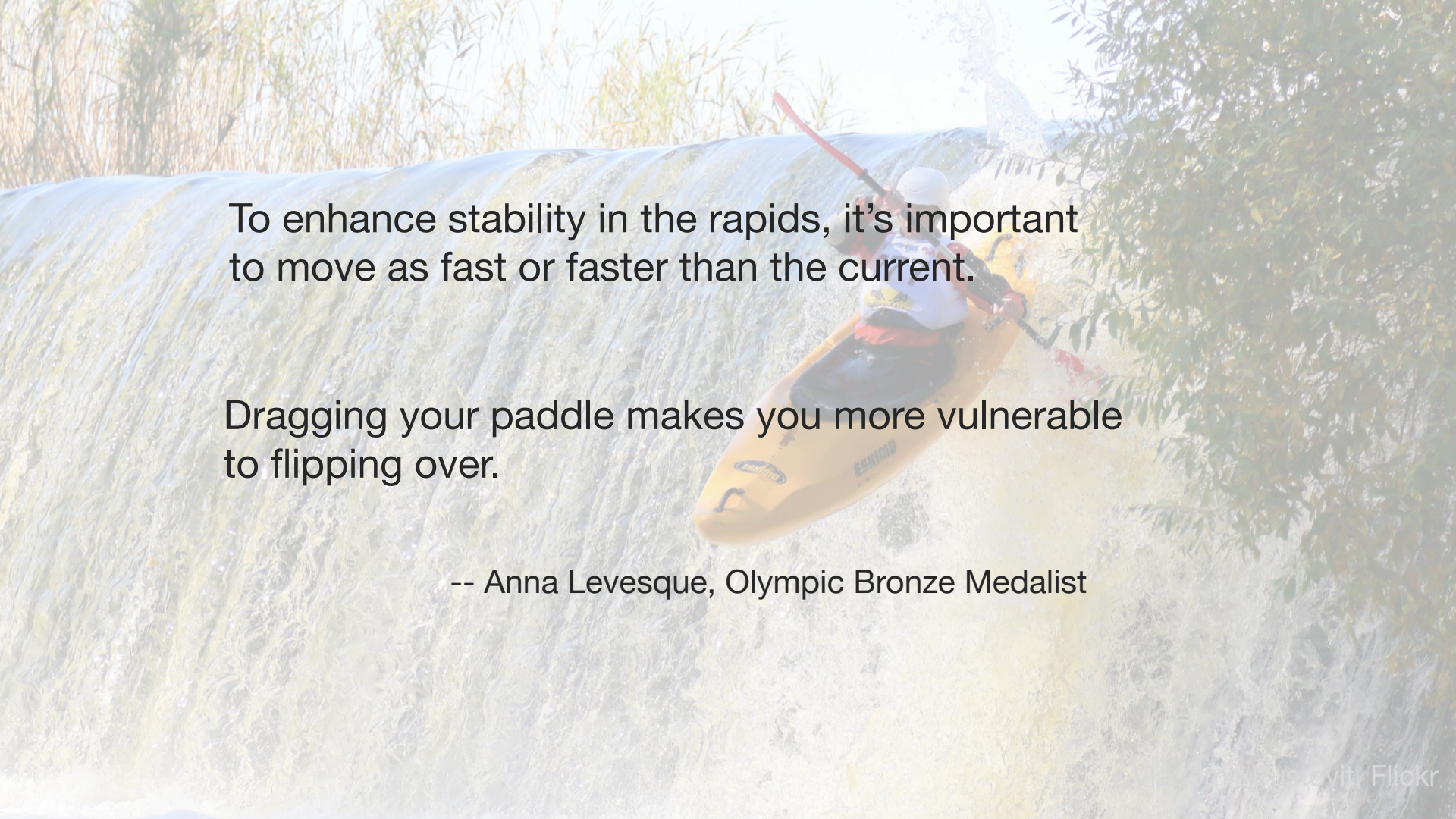
Marti Hearst

UC Berkeley

IJCAI Invited Talk

Melbourne, Aug 2017

Vladomir Pustovit, Flickr

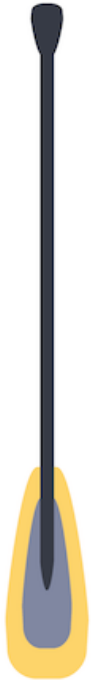


To enhance stability in the rapids, it's important to move as fast or faster than the current.

Dragging your paddle makes you more vulnerable to flipping over.

-- Anna Levesque, Olympic Bronze Medalist

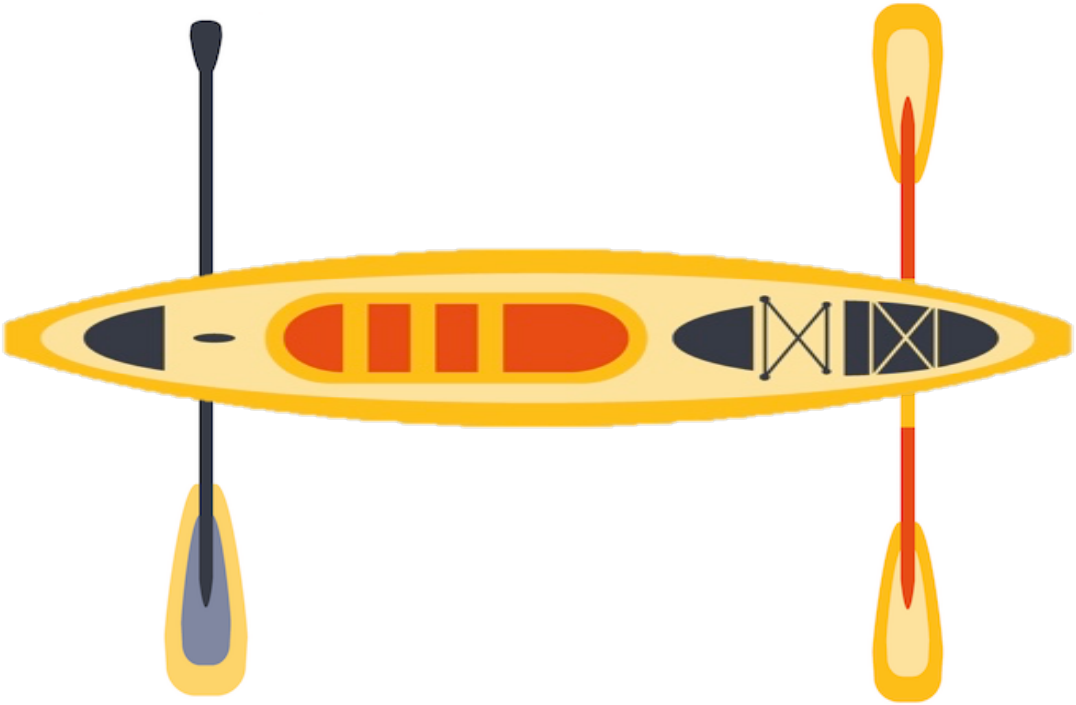
Two Simultaneous Disruptions Related to Technology



Job Automation

Teaching/Learning Online

Both Should be Benefitting by the Mitigating Factor of AI



Job Automation

Teaching/Learning Online

Can the two pull together for a better outcome?

Automation changing jobs

Changes to teaching / learning

Should AI Be Improving Learning More Than It Has To Date?

The Argument

- Although for decades technology has been changing the employment landscape, the change seems to be accelerating today.
- **One way** to address this is to help people help themselves by improving our methods for teaching and learning.
- **One method** for improving our teaching and learning is for AI to play a bigger role than it has to date.

Outline

Why We Need to **Accelerate** Learning

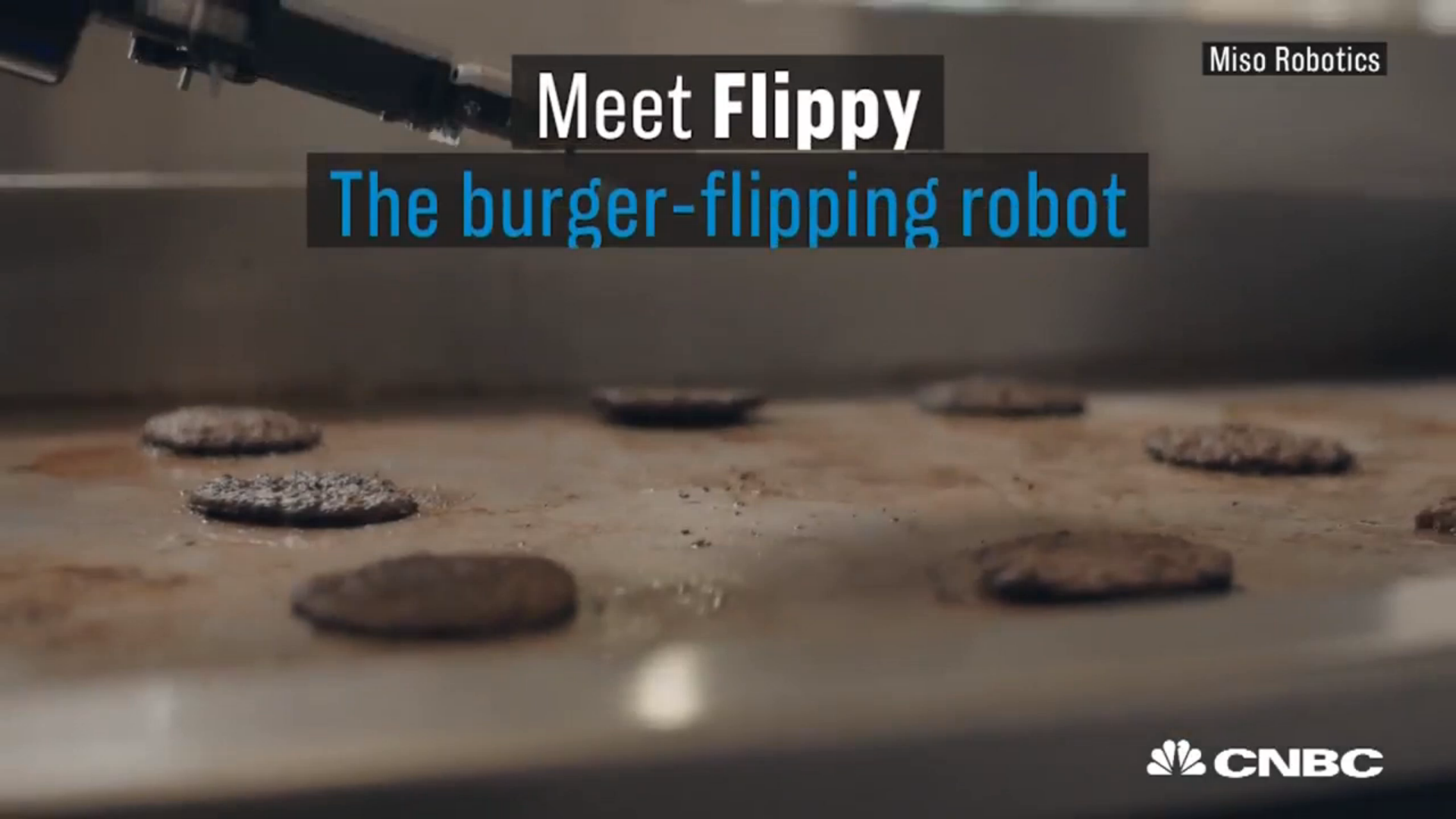
MOOCs, Active Learning, and Intelligent Tutoring Systems

Opportunities for AI to Improve Learning Tools

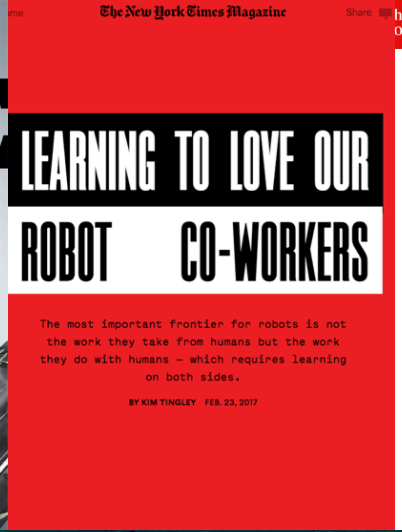
Caveats, a Conundrum, and Conclusions

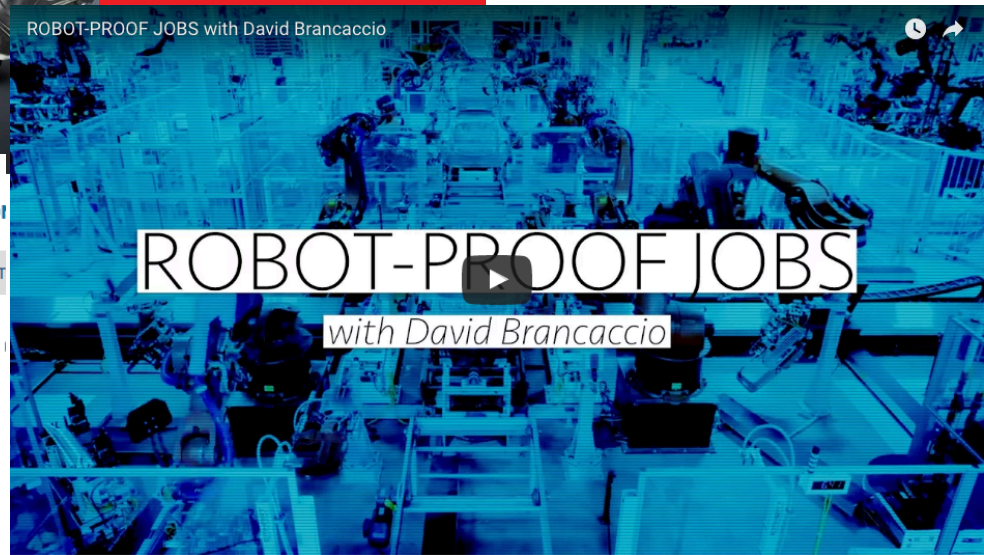

alBurger


Miso Robotics
Miso Robotics recently raised
$3.1 million in new funding


Miso Robotics
Meet Flippy
The burger-flipping robot
CNBC


Miso Robotics
And seem poised to replace workers
who perform the most repetitive tasks





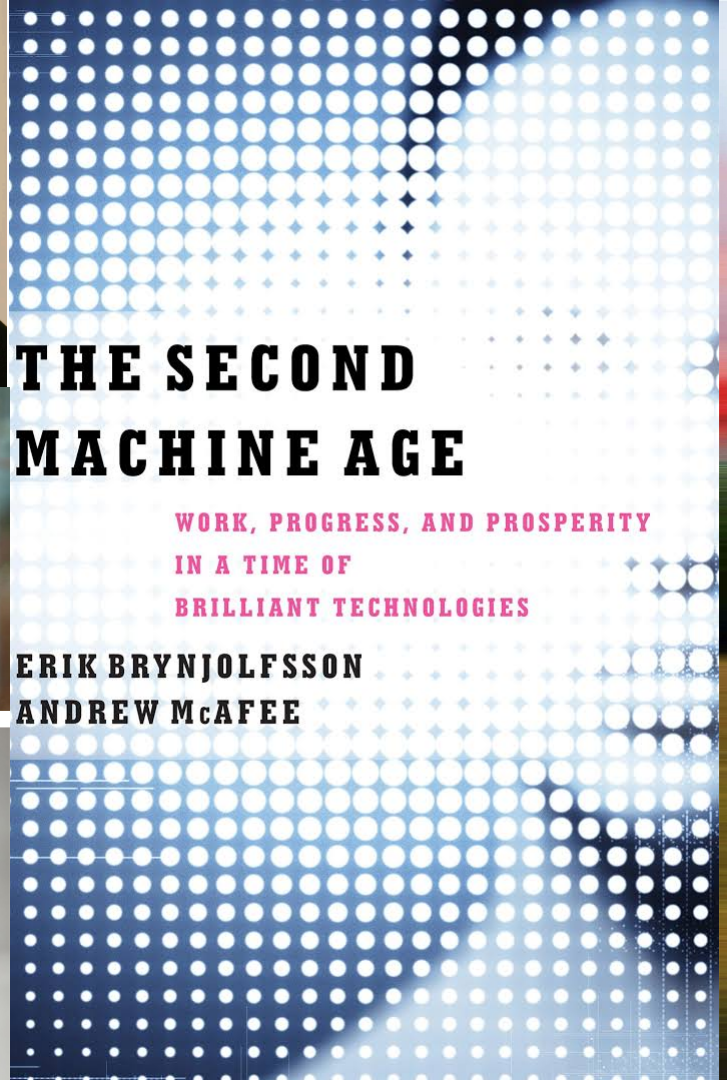
THE CHRONICLE OF HIGHER EDUCATION NEWS OPINIO

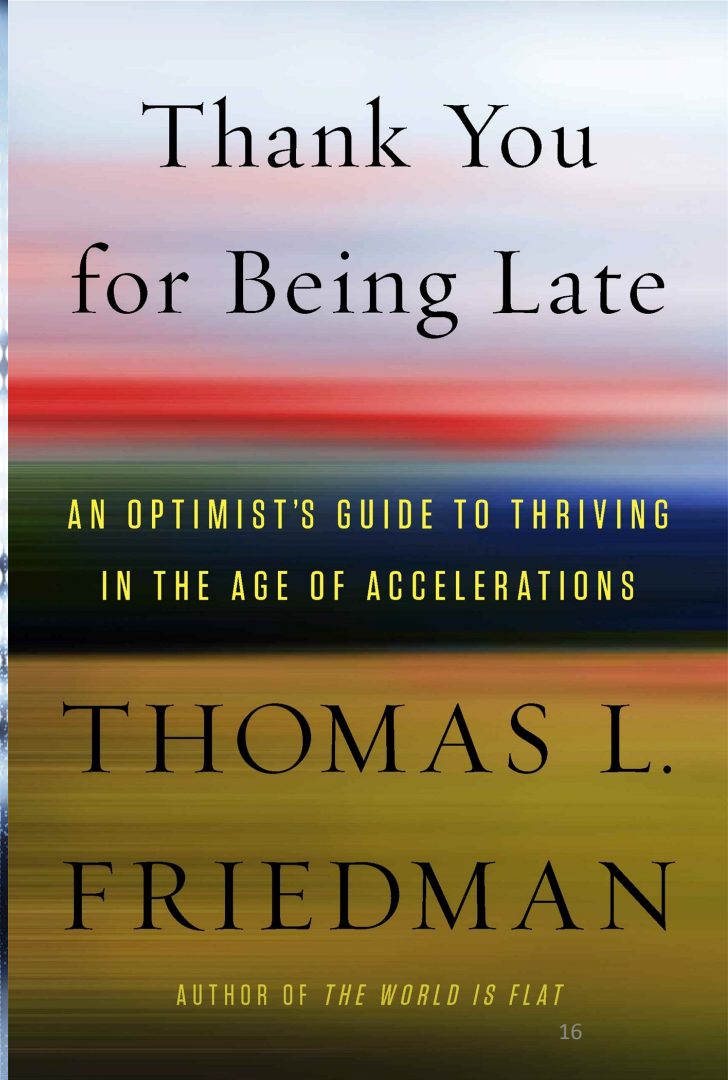
SECTIONS FEATURED: How to Train Effective Teachers What's New in Freshman Housing Your Daily Briefing T

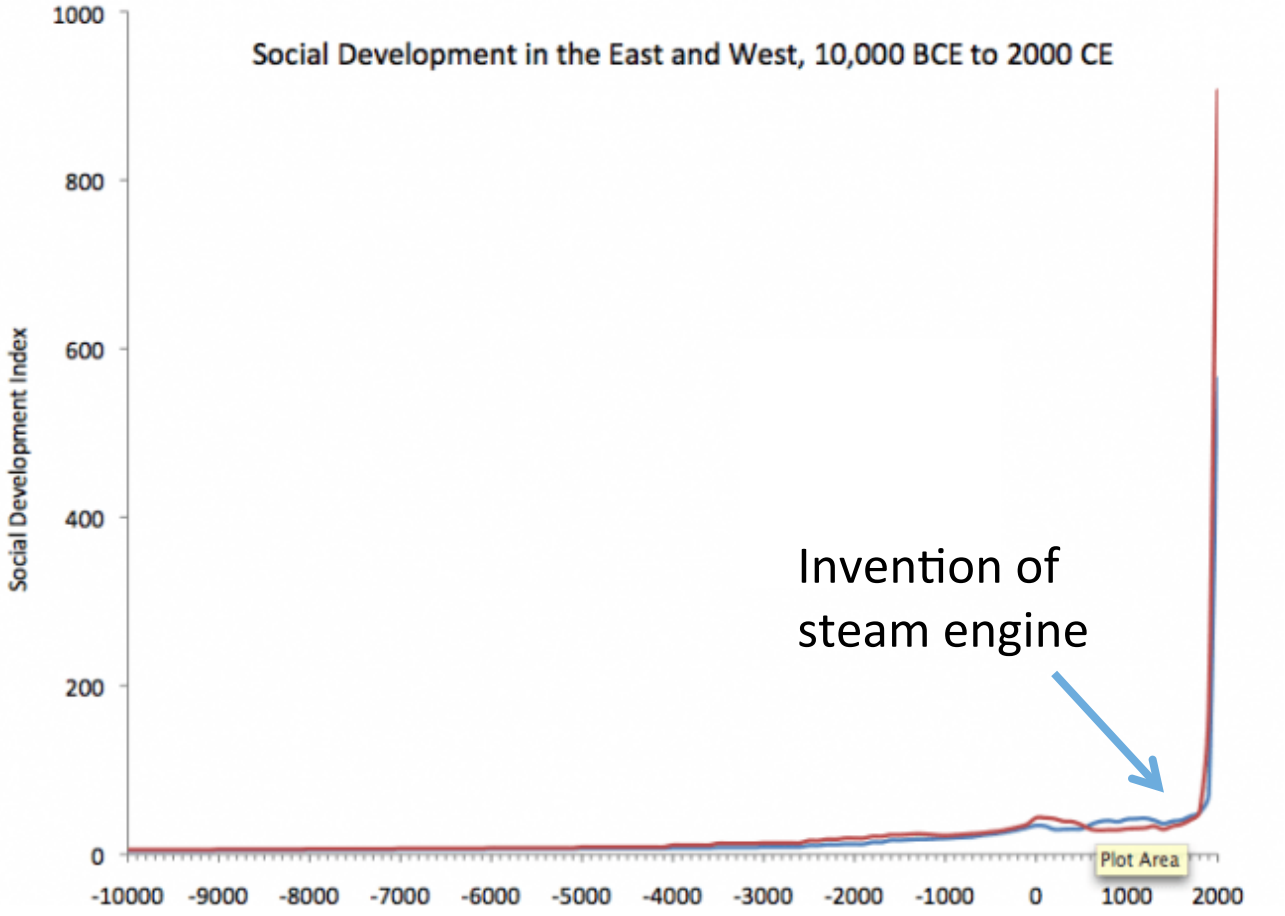
COMMENTARY

Robot-Proof: How Colleges Can Keep People Relevant in the Workplace

By Joseph E. Aoun | JANUARY 27, 2016


THE SECOND MACHINE AGE
WORK, PROGRESS, AND PROSPERITY IN A TIME OF BRILLIANT TECHNOLOGIES
ERIK BRYNJOLFSSON
ANDREW McAFEE

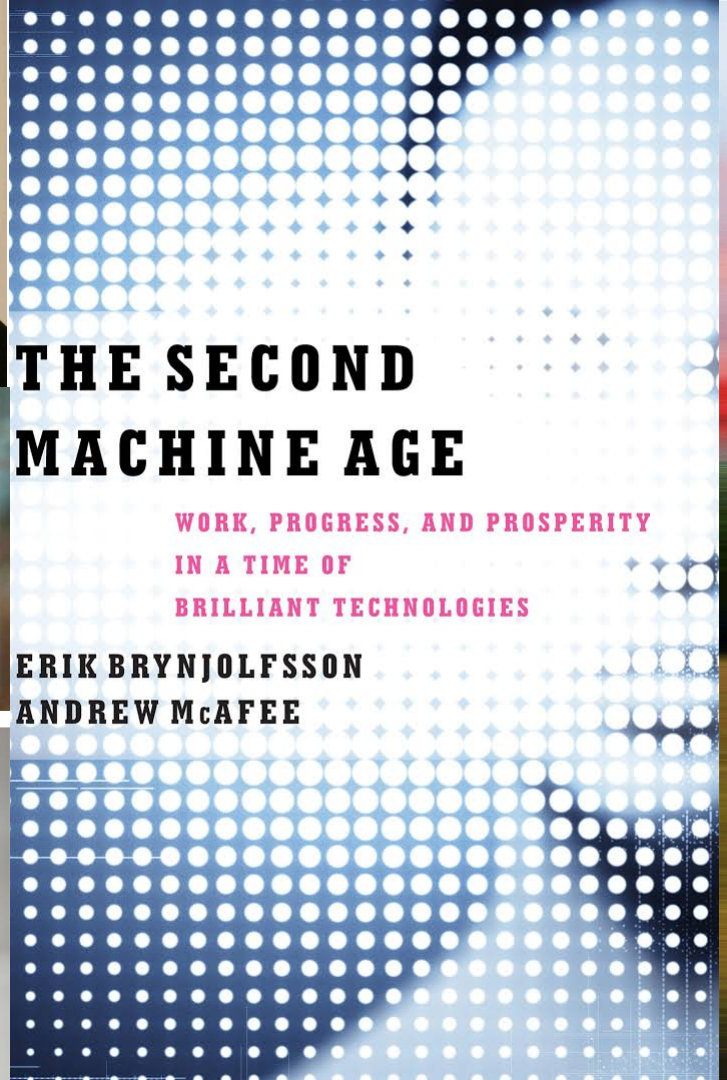

Thank You for Being Late
AN OPTIMIST'S GUIDE TO THRIVING IN THE AGE OF ACCELERATIONS
THOMAS L. FRIEDMAN
AUTHOR OF THE WORLD IS FLAT



Social Index relatively stable till the industrial revolution.

Today: Will simulating brain power be as big a revolution as simulating muscle power?

Brynjolfsson and McAfee, after Morris, *The Second Machine Age*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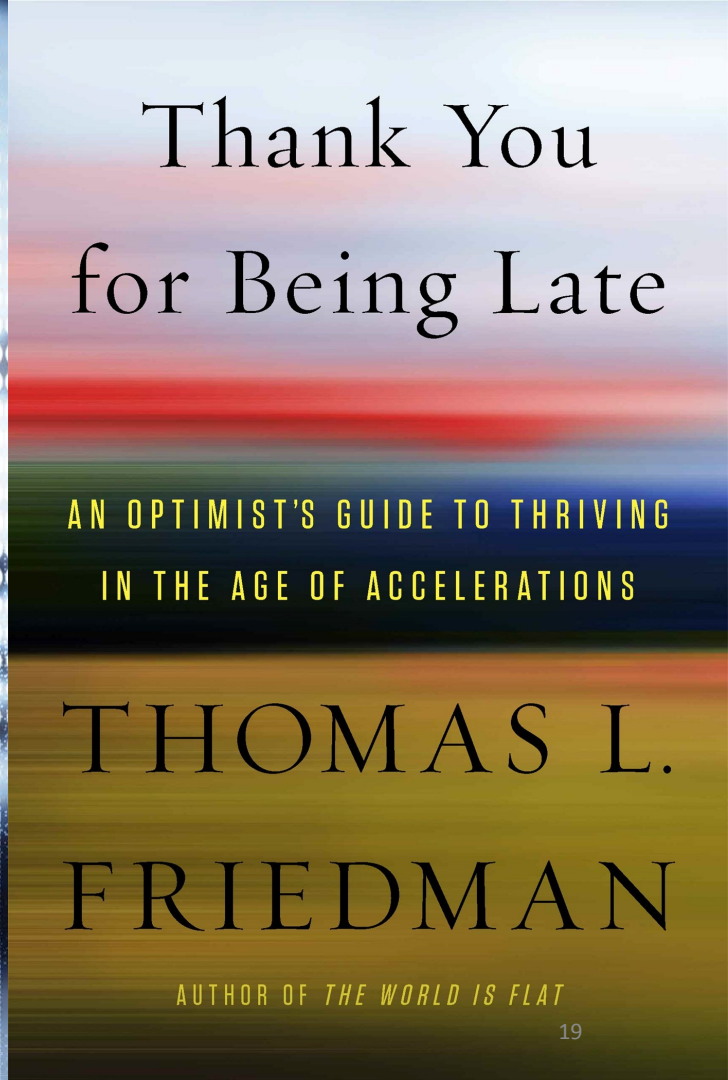
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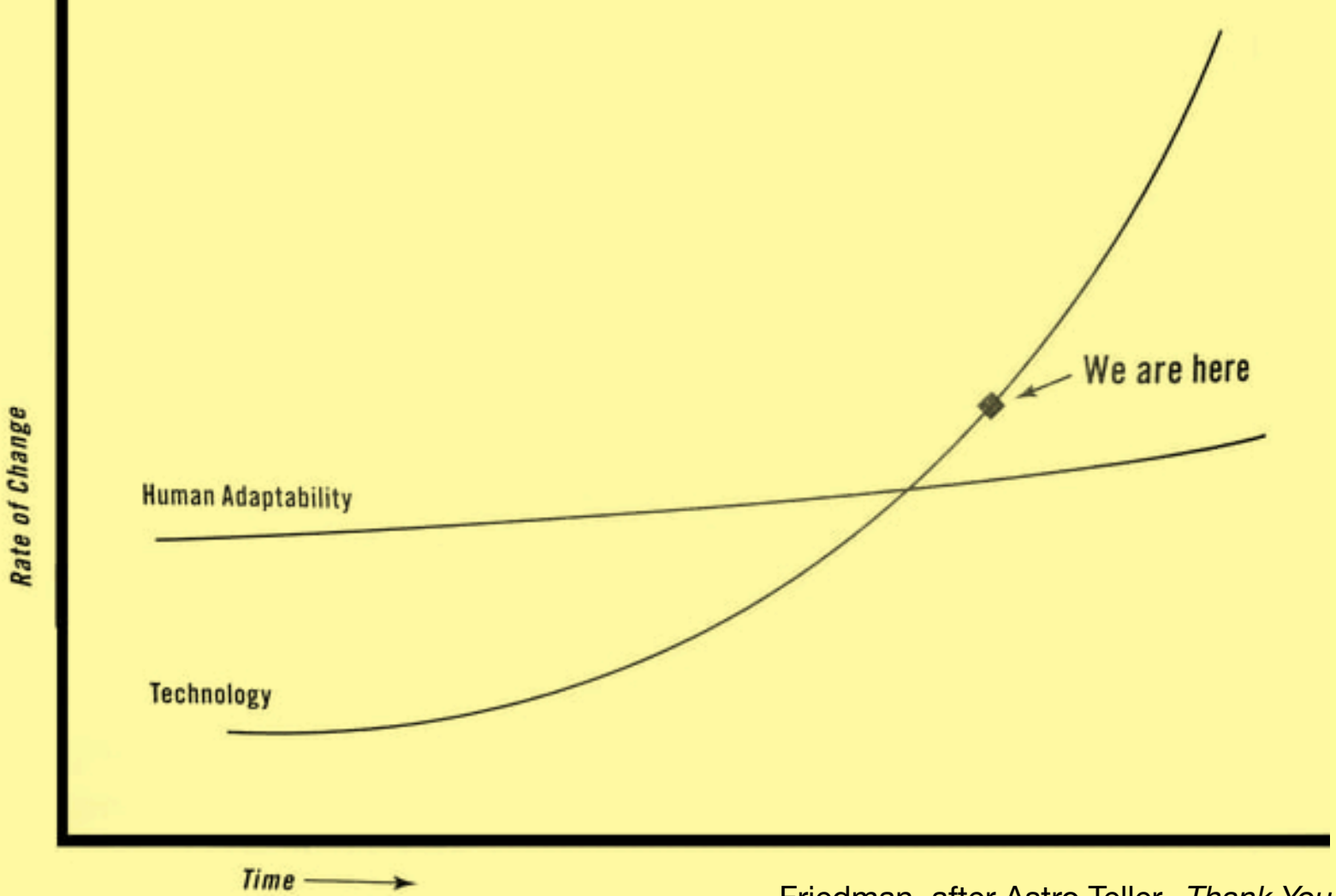
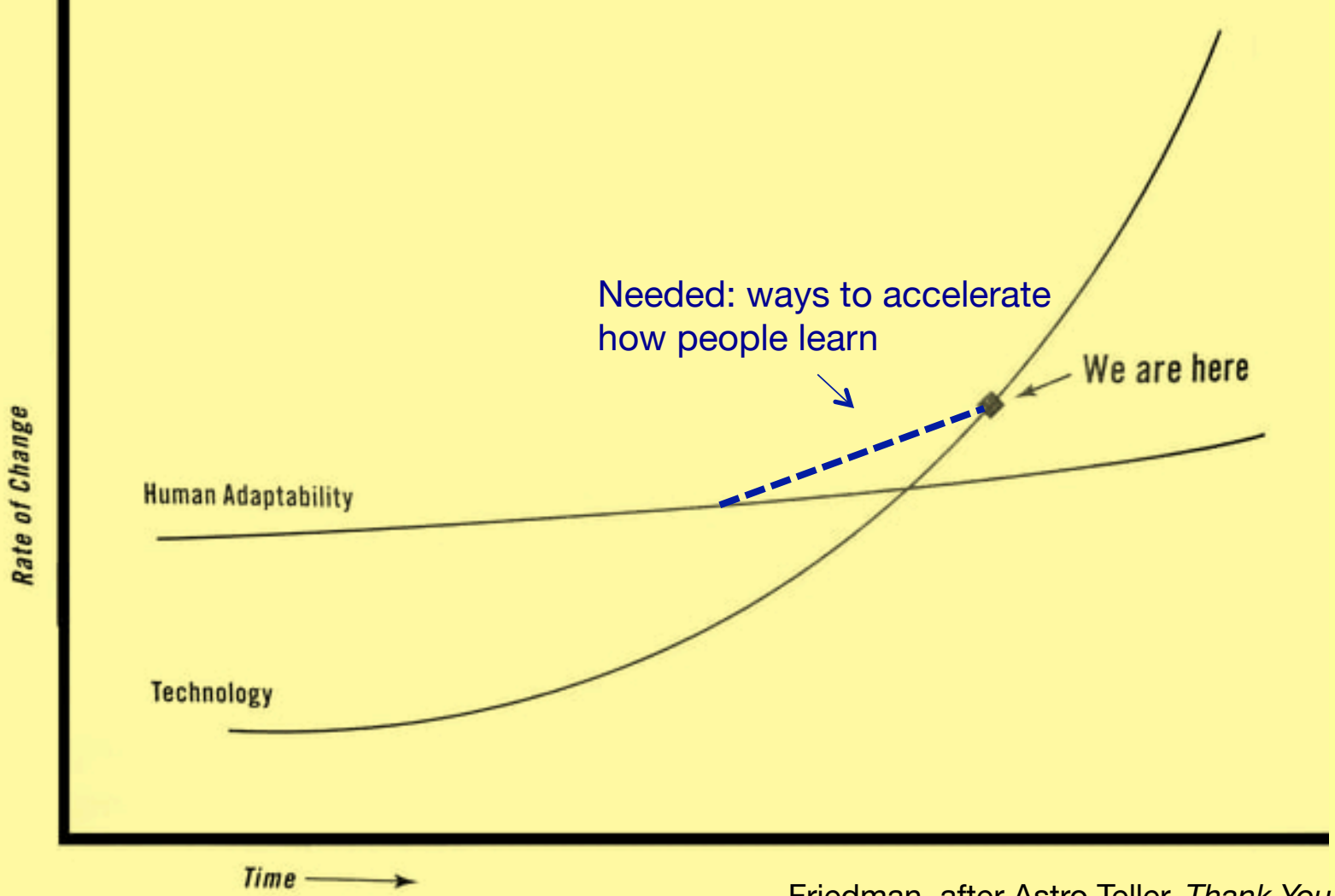


Friedman, after Astro Teller, *Thank You For Being Late*



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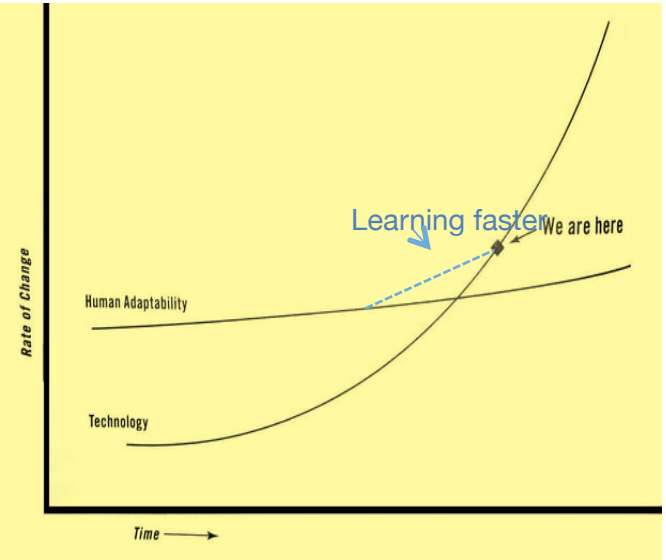


"There is a mismatch between the pace of change and our ability to develop the learning systems … that would enable citizens to get the most out of these accelerations and cushion their worst impacts."

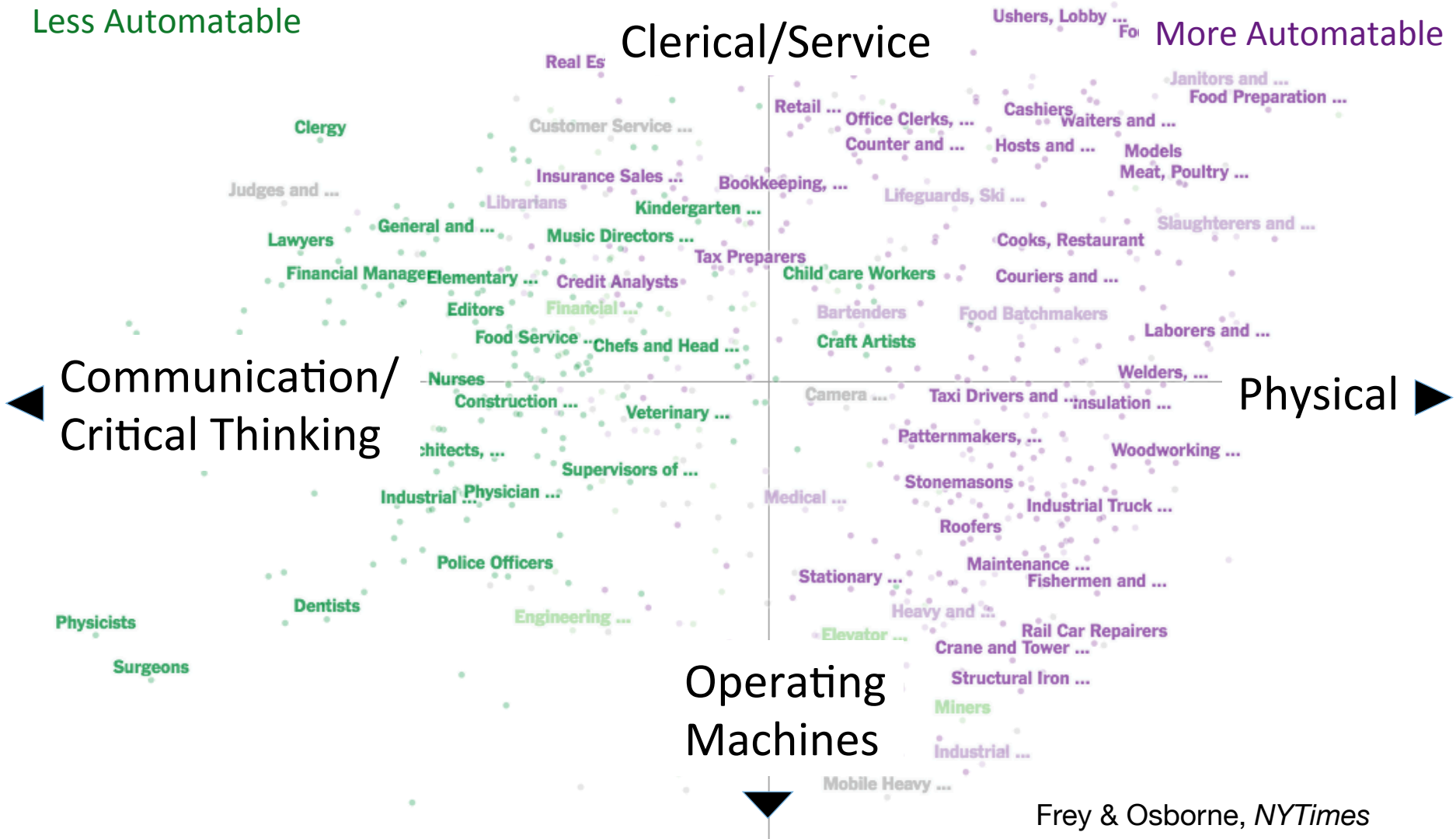
We can apply features that drive technological innovation to figure out how to enhance human's adaptability.

Friedman, *Thank You For Being Late*

Switching Careers Doesn't Have to Be Hard: Charting Jobs That Are Similar to Yours

By CLAIRE CAIN MILLER and QUOCTRUNG BUI JULY 27, 2017

Ezekiel Moreno, a veteran who was stocking groceries for a living, got a job making aerospace parts at M&M Manufacturing in Tulsa, Okla., after enrolling in a retraining program. Andrea Morales for The New York Times



Frey & Osborne, *NYTimes*

The Economist Calls for Innovation in Education

"As technology changes the skills needed for each profession, workers will have to adjust.

That will mean making education and training flexible enough to teach new skills quickly and efficiently.

The Role of AI in Innovation in Education

AI may itself help, by **personalizing learning** and by **identifying** workers' skills gaps and opportunities for retraining."

THIS IS AN ISSUE FOR KNOWLEDGE WORKERS TOO …

WHAT IS THE HALF-LIFE OF THE LATEST PROGRAMMING TOOL YOU LEARNED?


Caffe
Lasagne
theano
ELK
ML
Spark
TensorFlow
Keras
Torch
elastic

WOULDN’T YOU LOVE A WAY TO ACCELERATE YOUR LEARNING?

The Argument

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Online Learning Is Popular

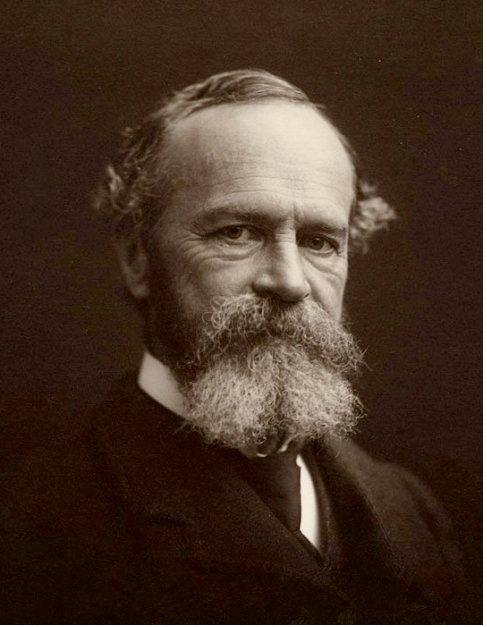
500+ Universities, 4200 courses, 35 Million Students

Salman Khan and https://www.class-central.com/report/moocs-2015-stats/

MOOCs Today

- Despite the classic curve of hype followed by backlash, MOOCs are going strong.
- Some of the early anticipated disruption has faded
- But other disruptions have happened and will continue far into the future (remote location, time shifting, etc).
- Of relevance to this talk is the disruption in how teaching and learning themselves take place in these computer-mediated courses.
- A key is the emphasis on **active learning.**

"A curious peculiarity of our memory is that things are impressed better by ***active*** *rather than by* ***passive*** *repetition."* -- William James, 1890



William James

"A curious peculiarity of our memory is that things are impressed better by ***active*** *rather than by* ***passive*** *repetition."* -- William James, 1890

GROUT, Edward M., lawyer; b. New York, Oct. 27, 1861; . Edward and Fanny (Mar- shall) G. ; grad. Colgate Un iv., 1884; admitted to bar, Dec, 1885; m. June 4, 1889 , Ida L. Loeschigk, Brooklyn, N. Y. Dem. candidate f or mayor of Brooklyn, 1895; elected pres. Borough of B rooklyn, New York City, 1897; judge-advocate and maj. 2d. brigade, N. G., N. Y., since Feb., 1894; active in urging consolidation of New York and Brooklyn from 1893-8; conducted contests in courts against gratuito us gifts of street railway franchise in Brooklyn, 189 2-5; Democrat. Wrote: "New York Should Own the Gas S upply," in Municipal Affairs, June, 1897. Residence: 860 Carroll St. Office, 189 Montague St., Brooklyn.

Question:
How best to memorize a text in 30 minutes?

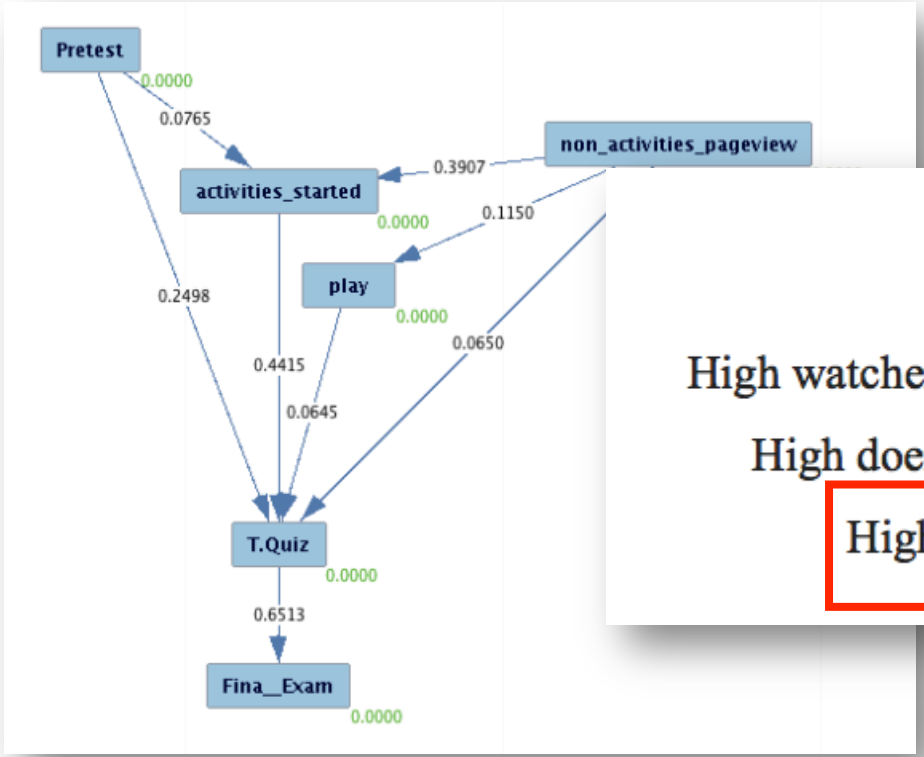
What % time reading and studying?

What % time practicing reciting from memory?

Answer: Study 1/3, Practice 2/3

Gates, Arthur Irving. Recitation as a factor in memorizing. No. 40. Science Press, 1917.

Active Learning Improves All Aspects of Learning

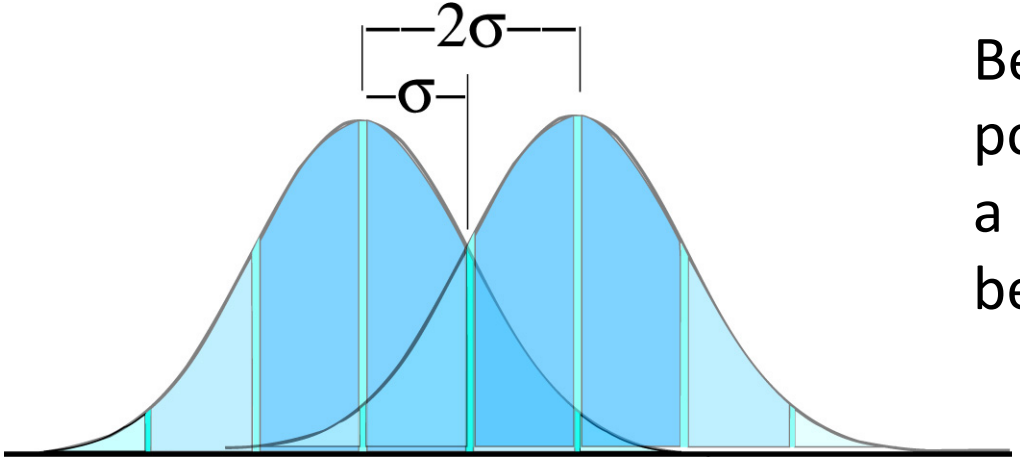


	Quiz		Final	
	Poor	Excellent	Poor	Excellent
High watcher only	46%	5%	38%	15%
High doer only	13%	42%	13%	16%
High both	2%	52%	0%	31%

Koedinger, et al. "Learning is not a spectator sport: ACM Learning@ Scale, 2015.

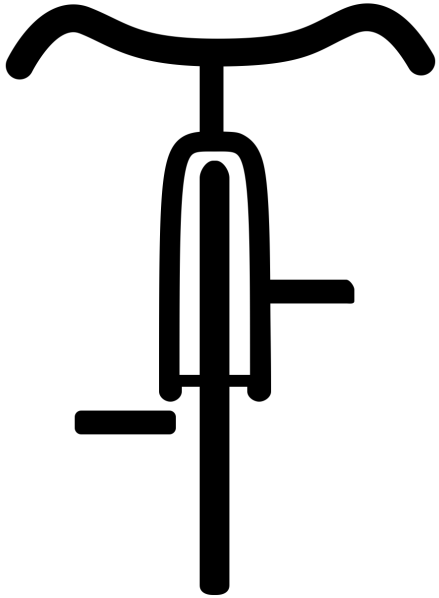
Effect Size: key measurement in education research

$$\frac{\text{[Mean of experimental group] − [Mean of control group]}}{\text{Standard Deviation}}$$



Benjamin Bloom (1984) popularized the notion of a “2-sigma” effect size as being the moonshot goal.

Sal Kahn



Mastery Learning

Requires Feedback and Practice

The laws of thermodynamics

First and Second Laws of Thermodynamics, as they apply to biological systems.

Introduction

What kind of system are you: open or closed? As it turns out, this is a physics question, not a philosophical one. You, like all living things, are an open system, meaning that you exchange both matter and energy with your environment. For instance, you take in chemical energy in the form of food, and do work on your surroundings in the form of moving, talking, walking, and breathing.

All of the exchanges of energy that take place inside of you (such as your

Energy and enzymes

Lessons

- Energy in metabolism
- **Laws of thermodynamics**
- Free energy
- ATP and reaction coupling
- Introduction to enzymes
- Enzyme regulation

Laws of thermodynamics

Learn

- Introduction to energy
- Types of energy
- First Law of Thermodynamics introduction
- Introduction to entropy
- Second Law of Thermodynamics
- Second Law of Thermodynamics and entropy
- Why heat increases entropy
- The laws of thermodynamics

Practice

Energy and thermodynamics

5 questions Practice

First law of thermodynamics | Chemical Processes | MCAT | Khan Academy

First Law of Thermodynamics

$\uparrow\downarrow U$ = internal energy of a gas

$\Delta U = Q$

Well, by enclosed we mean no particles,

Energy and thermodynamics

Go to lesson page

Which of the following forms of energy is correctly paired with its definition?

Choose 1 answer:

(A) Chemical energy - the energy contained within a system that is responsible for its temperature

(B) Thermal energy - the energy in a system due to its temperature

(−) Kinetic energy - the stored energy of an object due to its position

Kinetic energy is the energy associated with an object's motion. The stored energy of an object due to its position is potential energy.

(D) Potential energy - the energy associated with an object's motion

Give it another shot!

Try again, Get help, or skip for now.

Stuck? Watch a video or use a hint.

Do 5 problems

Try again

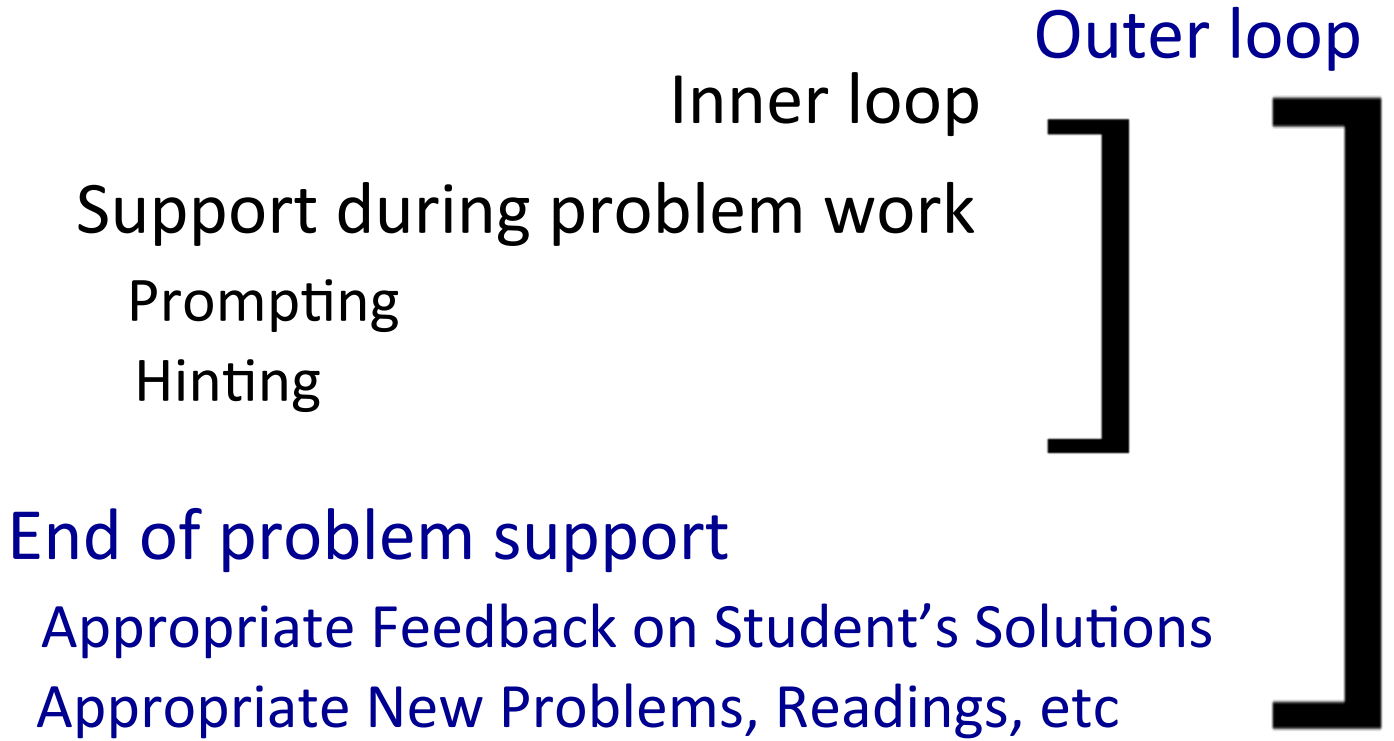
Tutoring Systems: Interactive Feedback Loops

Inner loop

Support during problem work

- Prompting
- Hinting

Tutoring Systems: Interactive Feedback Loops



Math

Explore | Mission

Want a personalized The World of Math experience?

Missions recommend what to learn next, help you remember what you've learned by mixing skills, and save your progress.

Start mission

Show less

Get started with a mission warm-up

First you'll do a few math problems to help us figure out where we should start. Don't worry if

Practice at your own pace

Your mission dashboard will give you tailored recommendations on what to learn next. You can

Remember what you've learned

Mastery challenges mix skills you've practiced in the past to help you remember what you've

100,000 Practice Problems

2013-08-08 13:40:00 GMT

We're excited to announce that Khan Academy has created lots of new math practice problems for the start of the school year! We now have 100,000 problems. We built out this content because we wanted to offer deeper, richer practice problems to help students rigorously master concepts.

Nice! Who's writing these math problems?

We've brought on a team of 15 math teachers, tutors, and professors to write creative problems that promote deep conceptual understanding of a range of math topics. To ensure our content is high-quality and ms bas

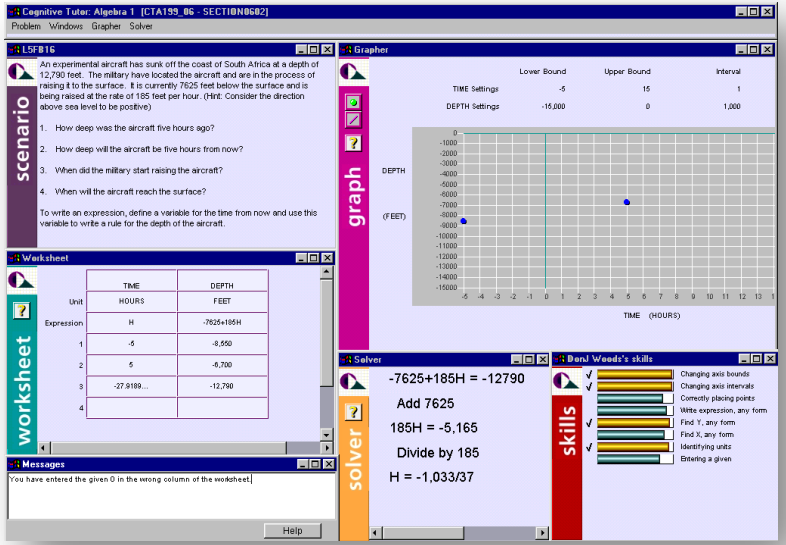
15 math teachers, tutors, and professors

And for teachers getting ready for Common Core, we're excited to let you know that we're creating new math problems that comprehensively and rigorously cover the Common Core State Standards. We've already written new questions for many of the 4th-8th grade standards and will cover all of the Math Standards by Fall 2014. You can check out an up-to-date mapping of our practice problems to the Common Core here.

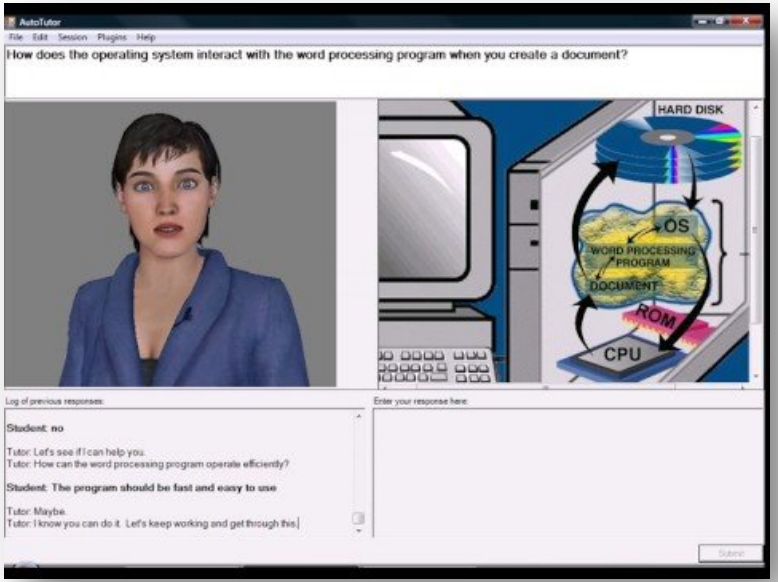
Can I see an exam

Google Chrome

Sophisticated Intelligent Tutoring Systems



Cognitive Tutor (Algebra)



Autotutor

Do Intelligent Tutoring Systems Work?

- Meta-meta-analysis (Kulik & Fletcher, Review of Educational Research, 2016)
  - Took into account important controlling factors
  - Found moderately strong positive effects (.4 - .6 typically)
  - An important factor was "adequacy of the program implementation"

  "The evaluations show that ITSs typically raise student performance well beyond the level of conventional classes and even beyond the level achieved by students who receive instruction from… human tutors."

WHY AREN'T INTELLIGENT TUTORING SYSTEMS DEPLOYED EVERYWHERE?

Ryan Baker

Int J Artif Intell Educ (2016) 26:600–614
DOI 10.1007/s40593-016-0105-0

ARTICLE

Stupid Tutoring Systems, Intelligent Humans

Ryan S. Baker[1]

Received: 8 June 2015 / Accepted: 3 February 2016 / Published online: 22 February 2016

Abstract The initial vision for intelligent tutoring systems involved powerful, multi-faceted systems that would leverage rich models of students and pedagogies to create complex learning interactions. But the intelligent tutoring systems used at scale today are much simpler. In this article, I present hypotheses on the factors underlying this development, and discuss the potential of educational data mining driving human decision-making as an alternate paradigm for online learning, focusing on intelligence amplification rather than artificial intelligence.

Ryan Baker

"Stupid" Tutoring Systems, Intelligent Humans

The initial vision for intelligent tutoring systems involved powerful systems that would leverage rich user models to create complex learning interactions.

But the intelligent tutoring systems being used at scale today are much simpler.

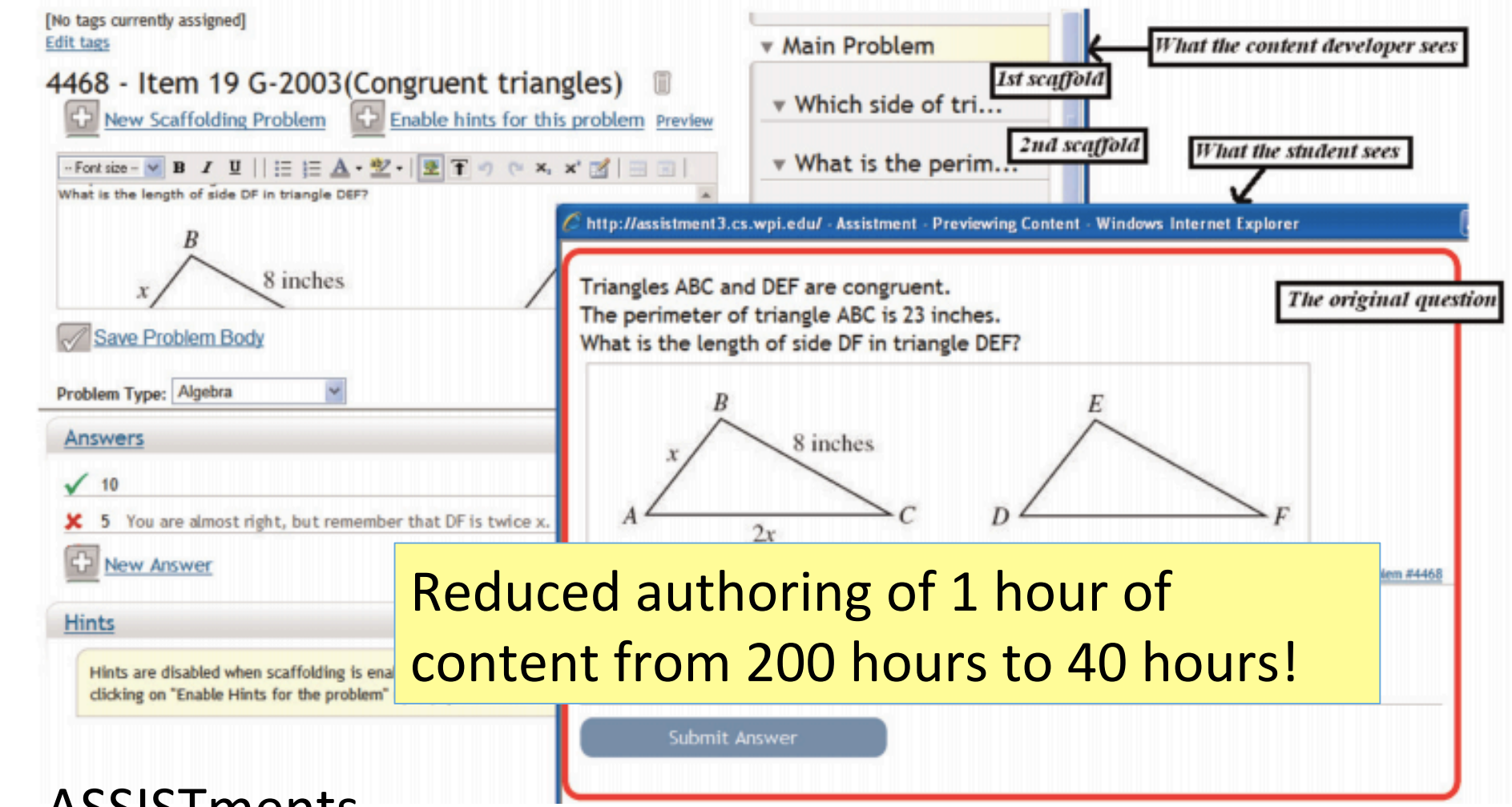
Baker, IJAIE 26 (2), 2016.

Ryan Baker

"Stupid" Tutoring Systems, Intelligent Humans

Perhaps we do not in fact need intelligent tutoring systems. Perhaps instead what we need, what we are already developing, is stupid tutoring systems. Tutors that do not, themselves, behave very intelligently. But tutors that are designed intelligently, and that leverage human intelligence.

Baker, IJAIE 26 (2), 2016.



Reduced authoring of 1 hour of content from 200 hours to 40 hours!

ASSISTments

Raqqaz et al, IEEE Trans Learn Tech 2009

WE NEED TO ACCELERATE THIS: PEOPLE ARE DOING IT BY HAND!

Eriz Mazur
Physics

Peter Norvig
AI

Pavel Pevzner
Bioinformatics

The Conventional Lecture is Dead!

EDUCATION

Farewell, Lecture?

A physics professor describes his evolution from lecturing to dynamically engaging students during class and improving how they learn.

Eric Mazur

Discussions of education are generally predicated on the assumption that we know what education is. I hope to convince you otherwise by recounting some of my own experiences. When I started teaching introductory physics to undergraduates at Harvard University, I never asked myself how I would educate my students. I did what my teachers had done—I lectured. I thought that was how one learns. Look around anywhere in the world and you'll find lecture halls filled with students and, at the front, an instructor. This approach to education has not changed since before the Renaissance and the birth of scientific inquiry. Early in my career I received the first hints that something was wrong with teaching in this manner, but I had ignored it. Sometimes it's hard to face reality.

When I started teaching, I prepared lecture notes and then taught from them. Because my lectures deviated from the textbook, I provided students with copies of these lecture

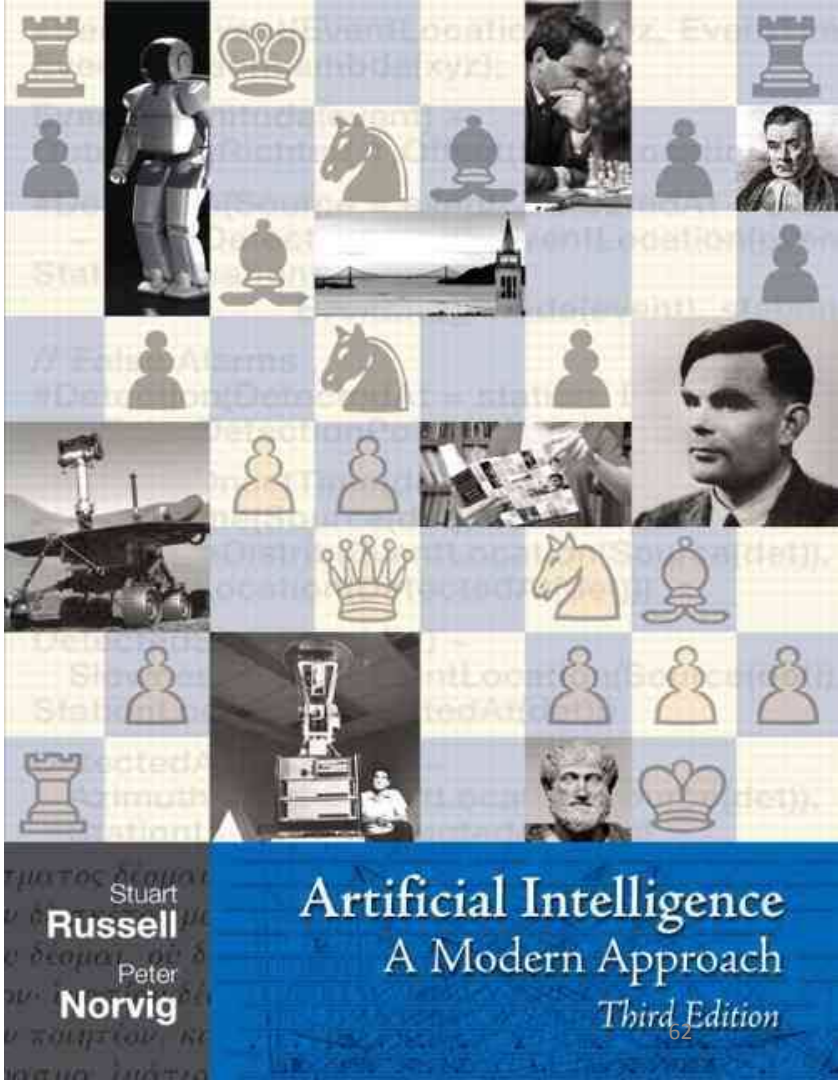
Click here. Students continually discuss concepts among themselves and with the instructor during class. Discussions are spurred by multiple-choice conceptual questions that students answer using a clicker device. See supporting online text for examples of such "clicker questions."

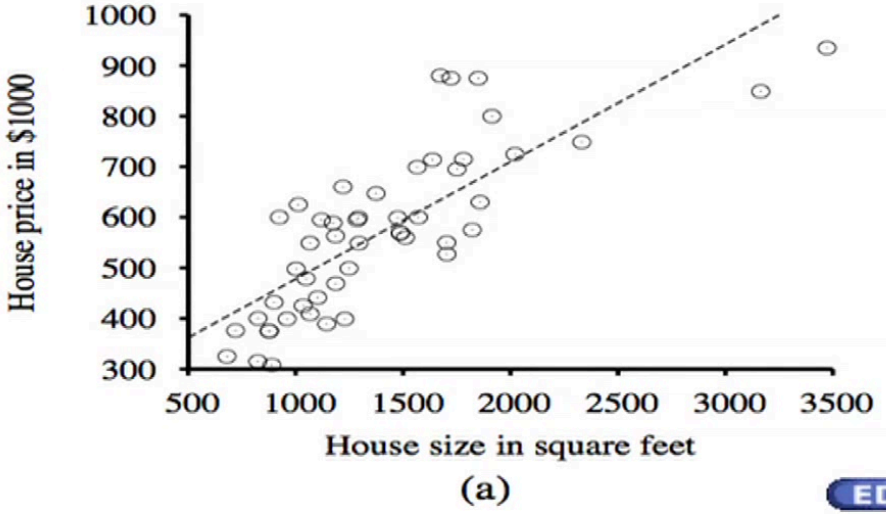
motion, which states that the force of object A on object B in an interaction between two objects is equal in magnitude to the force of B on A—it sometimes is known as "action is reaction." One day, when the course had progressed to more complicated material, I decided to test my students' understanding of this concept not by doing traditional problems, but by asking them a set of basic conceptual questions (*1*, *2*). One of the questions, for example, requires students to compare the forces that a heavy truck and a light car exert on one another when they collide. I expected that the students would have no trouble tackling such questions, but much to my surprise, hardly a minute after the test began, one student asked, "How should I answer these questions? According to what you taught me or according to the way I usually think about

That was when it began to dawn on me that

Mazur, Science 323, Jan 2009

Peter Norvig





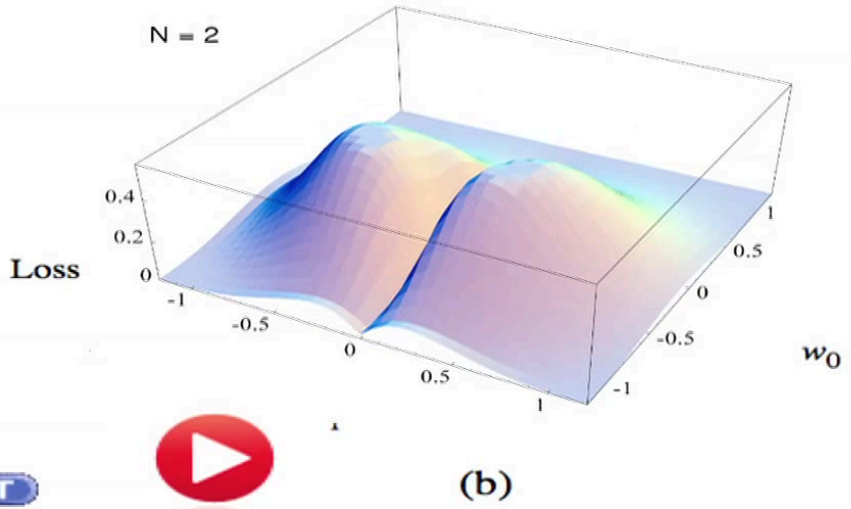
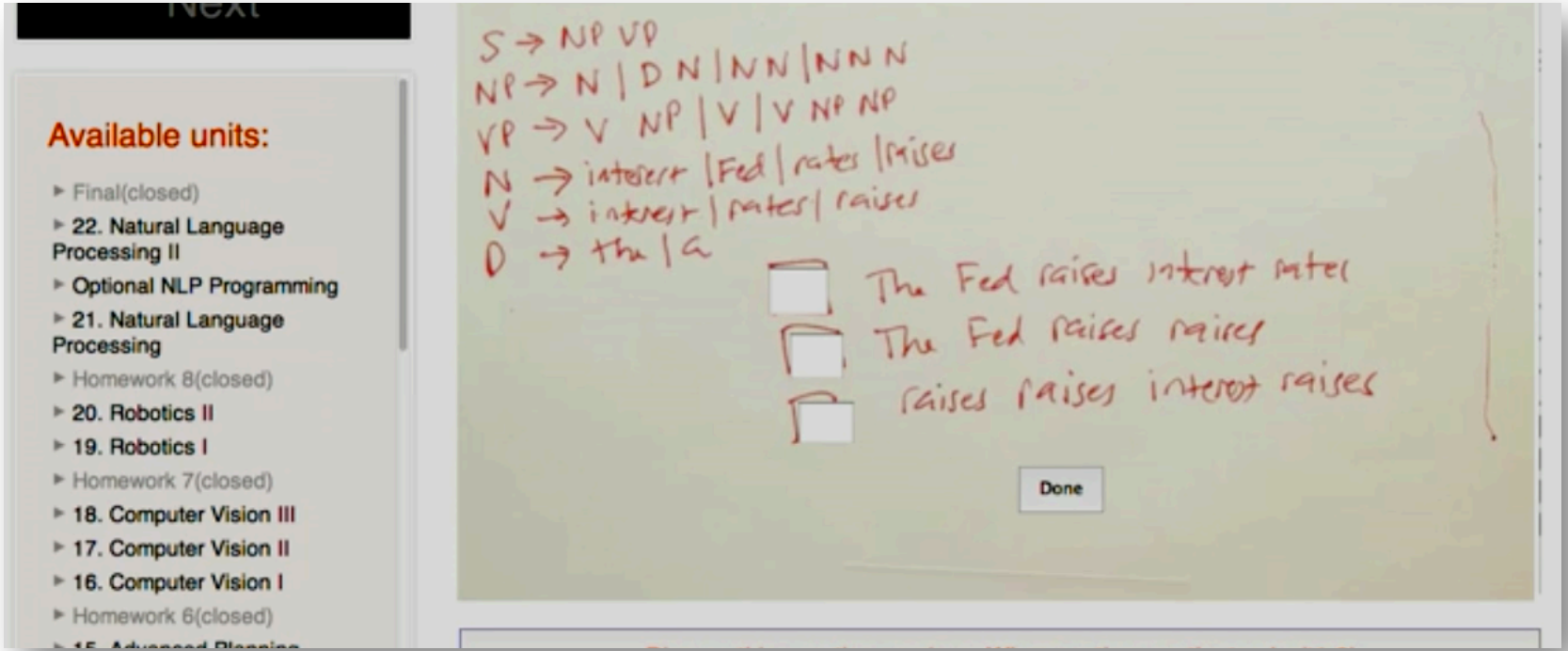


Figure 18.13 (a ıts of price versus floor space of houses for sale in Berkeley, CA, in July 2009, the linear function hypothesis that minimizes squared error loss: $y = 0.232x$, 200); Plot of the loss function $\sum_j (w_1 x_j + w_0 - y_j)^2$ for various values of w_0, w_1. Note that the loss function is convex, with a single global minimum.

Norvig's Early Active Learning Exercise



Peter Norvig's TED talk

Pavel Pevzner

One-on-one education is best.

But we can't afford it, and if we could, there maybe are not enough tutors.

Instead, we should combine computers with teaching.

ISMB 2017 Keynote talk

Pavel Pevzner

Massive Adaptive Interactive Textbook

Online bioinformatics platform

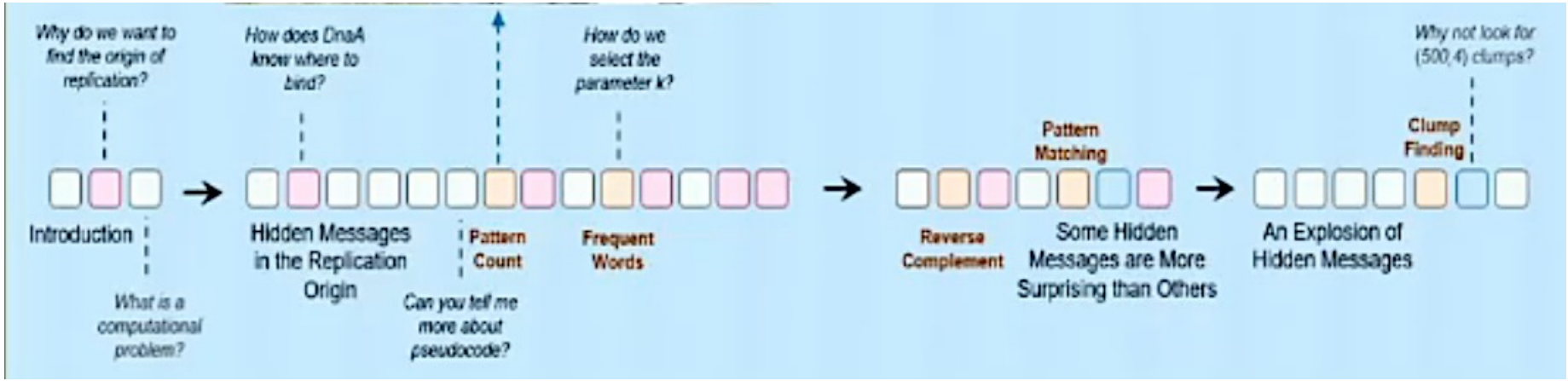
100+ autograded programming challenges

Stop and think exercises, code challenges, detours

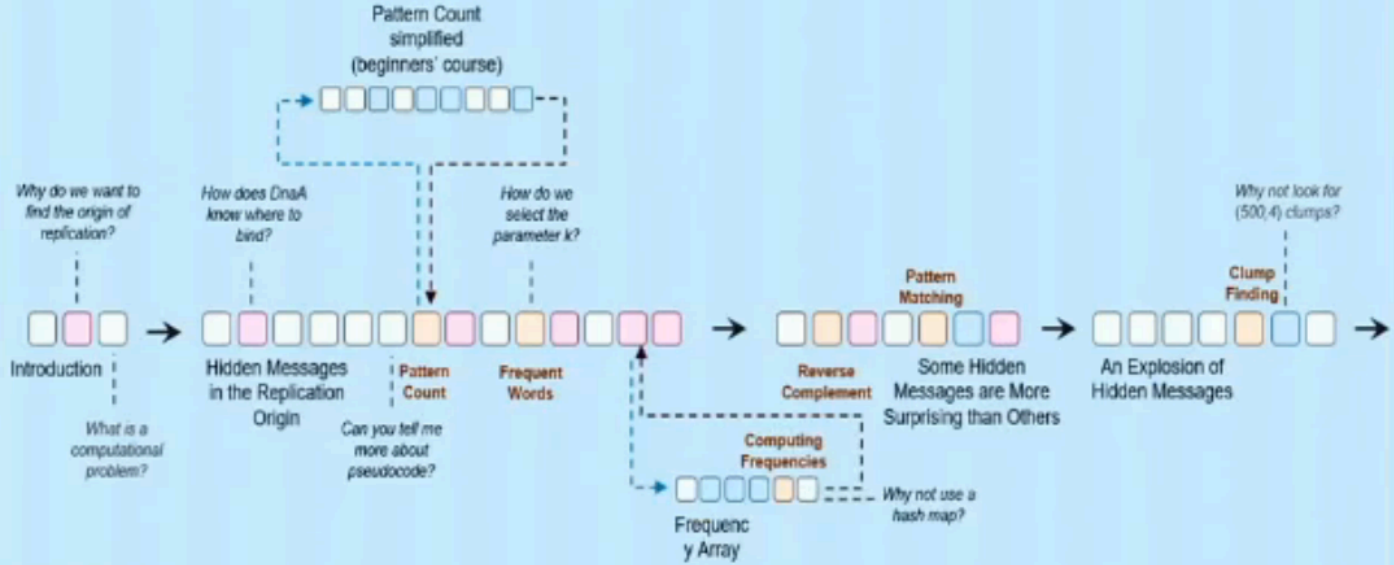
As soon as a student fails, they are directed to a new module to address the learning breakdown.

ISMB 2017 Keynote talk

Programs, Challenges, FAQs throughout

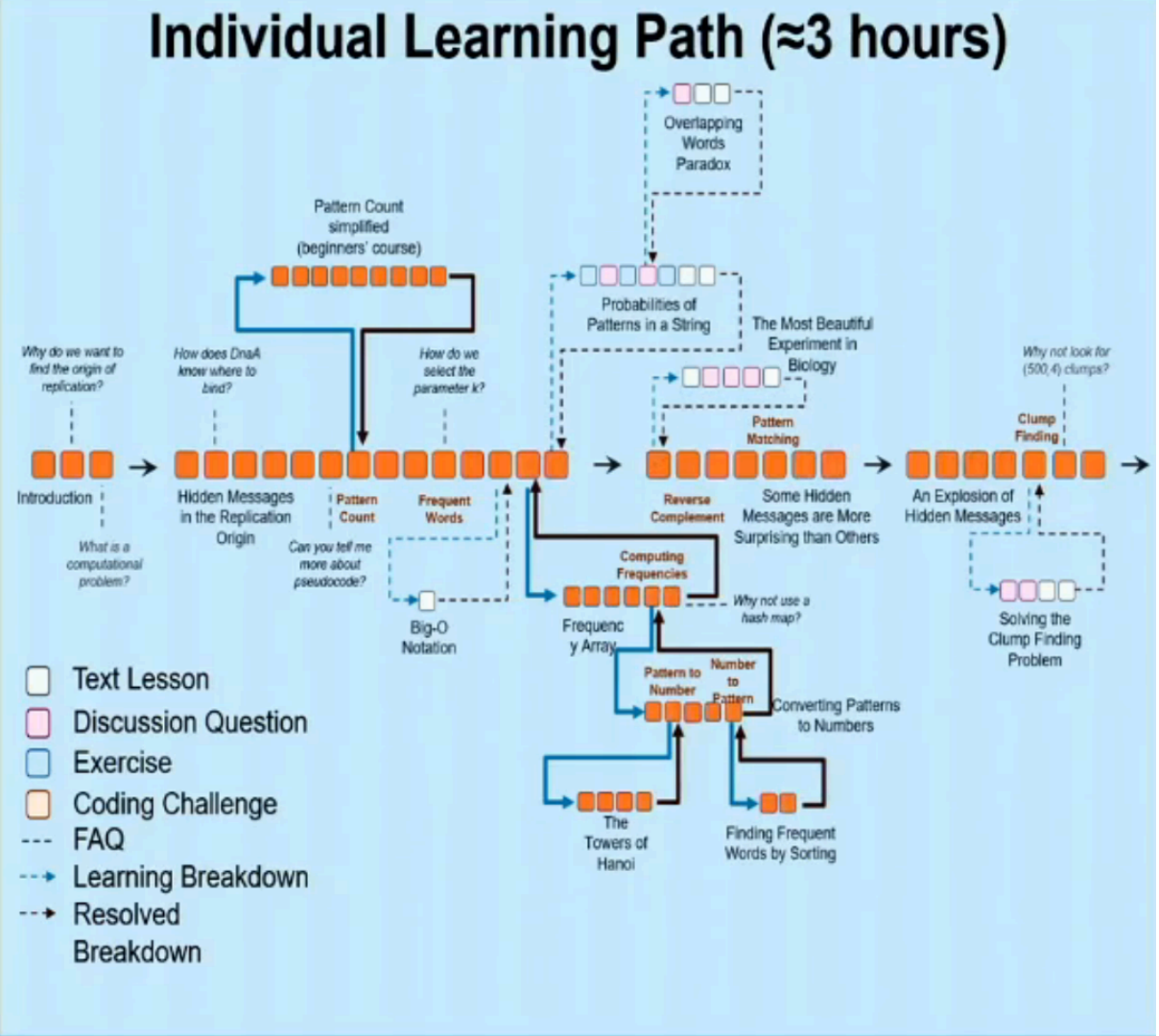


ISMB 2017 Keynote talk



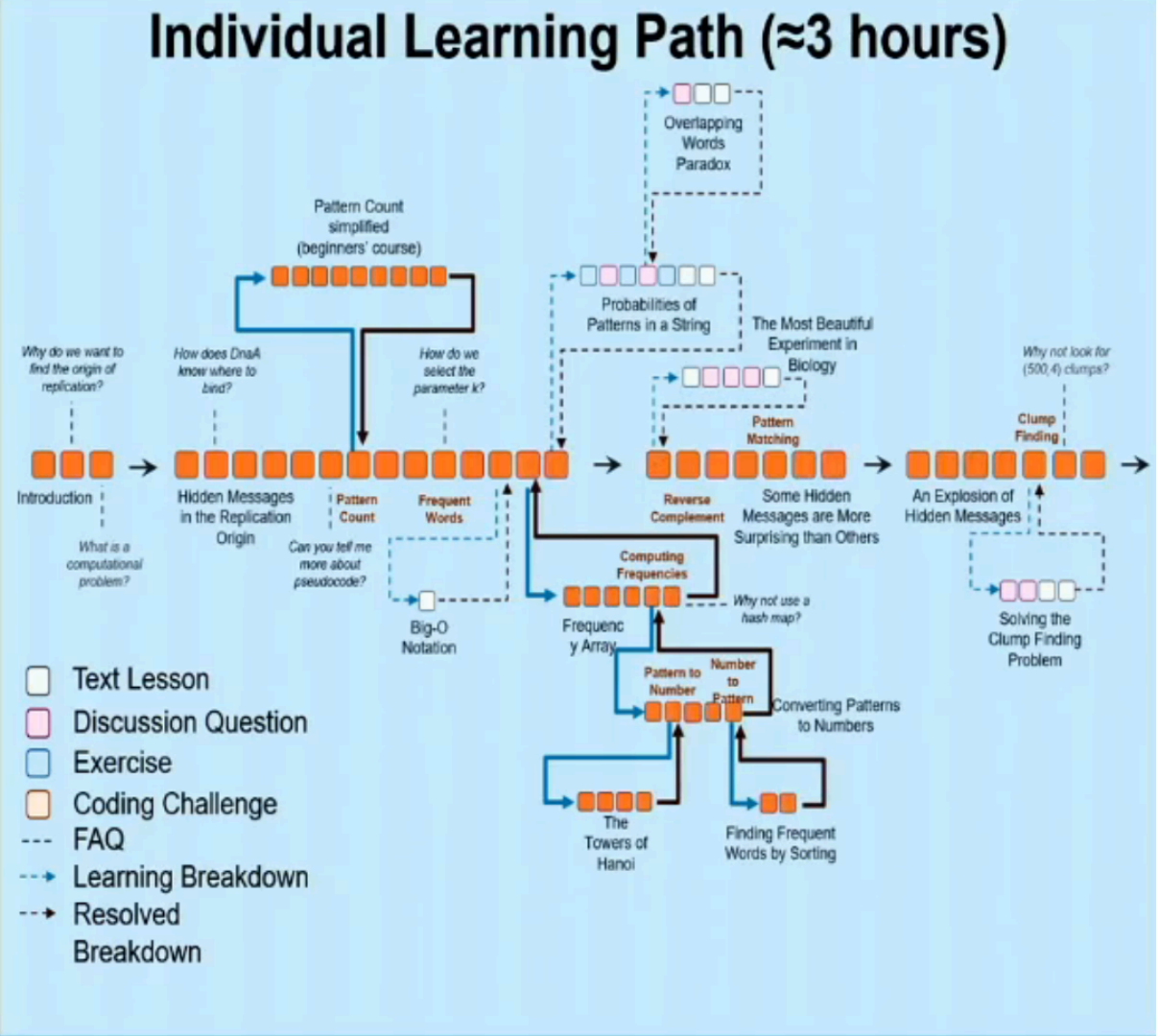
If a student makes an error, they are directed to a sub-branch to address the relevant misunderstanding.

ISMB 2017 Keynote talk



With thousands of students taking the course, more and more unexpected errors are uncovered.

ISMB 2017 Keynote talk



More than a dozen people and 7000 hours development time already!

ISMB 2017 Keynote talk

Karthik Muralidharan

Developing Countries Perspective

- Hardware-focused interventions for home or school seem to have no positive impact on learning outcomes
- Pedagogy-focused computer-aided learning programs that allow students to review grade-appropriate content at their own pace do better, but gains are modest (.1-.2)
- Interventions that deliver the largest gains appear to be those that use technology to also personalize instruction.

Muralidharan et al, CESifo Working Paper, No. 6328, 2017

Karthik Muralidharan

MindSpark Deployment in India

- 10 years of development
  - >45,000 test questions
  - >1M questions administered per day
- Can tailor suggestions to students
- Student errors are analyzed to refine suggestions
- This allows for identification of long-tail misconceptions
- Show .36 learning gain in math and .22 in Hindi in randomized controlled studies.
- HOWEVER all of this tailoring work has been done manually.

Muralidharan et al, CESifo Working Paper, No. 6328, 2017

Long Tail Student Misperceptions: Which Number is Larger?

“27 is larger than 3”

Long Tail Student Misperceptions: Which Number is Larger?

“1/27 is larger than 1/39”

THERE ARE MANY MORE EXAMPLES…

Claim: If There Were An Easy-to-Use Semi-Automated Way To Develop these Systems, People Would Use It

Why don’t we have good software for developing autograders, question suggestors, etc?

Outline

Why We Need to **Accelerate** Learning

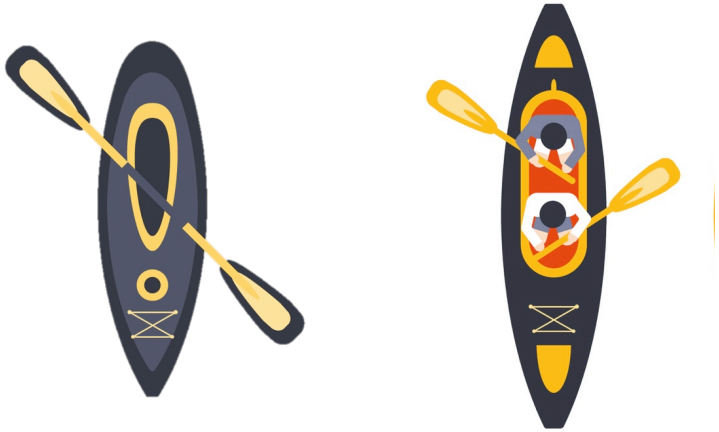
MOOCs, Active Learning, and Intelligent Tutoring Systems

Opportunities for AI to Improve Learning Tools

Caveats, a Conundrum, and Conclusions

Opportunities for AI to Intersect with Learning

Zone of Proximal Development

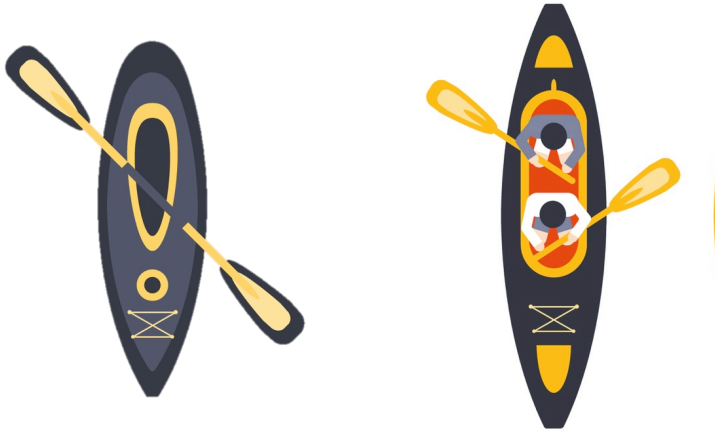


Peer Learning

These are two kinds of interventions for which many studies show at least moderate learning gains.

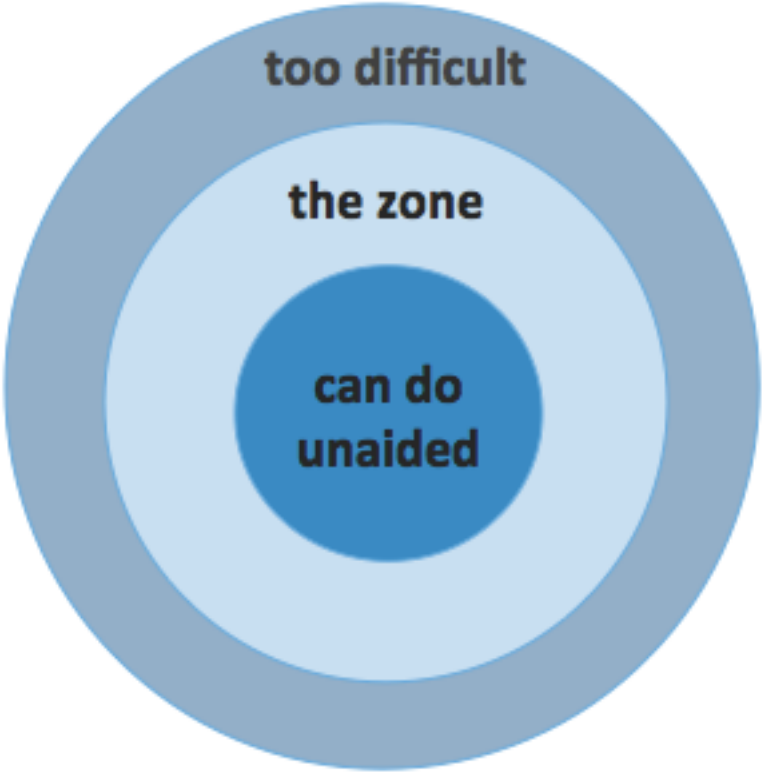
Opportunities for AI to Intersect with Learning

Zone of Proximal Development



Peer Learning

The Zone of Proximal Development



Zone of Proximal Development

Giving students the hardest tasks they can do at a given point can lead to learning gains.

Suggesting steps in the zone can make active learning more efficient and effective.

Wass & Golding 2014

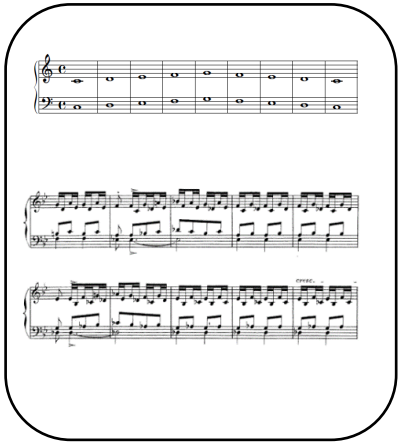
Idea: Detect Cognitive Load; Dynamically Adjust Problem Difficulty

Beste Yuksel
USF

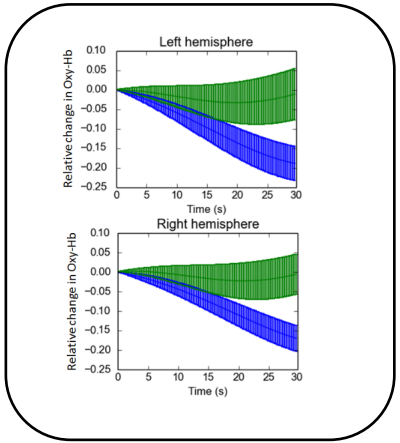
Yuksel et al, CHI 2016

BACh

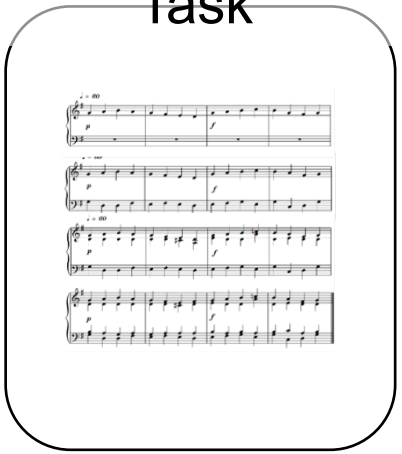
Training Task: Easy vs Hard Pieces



Modeling High and Low Cognitive Workload

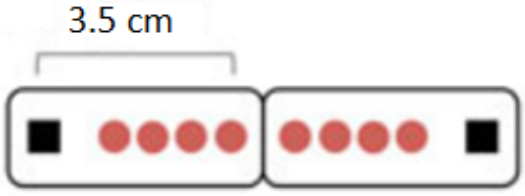


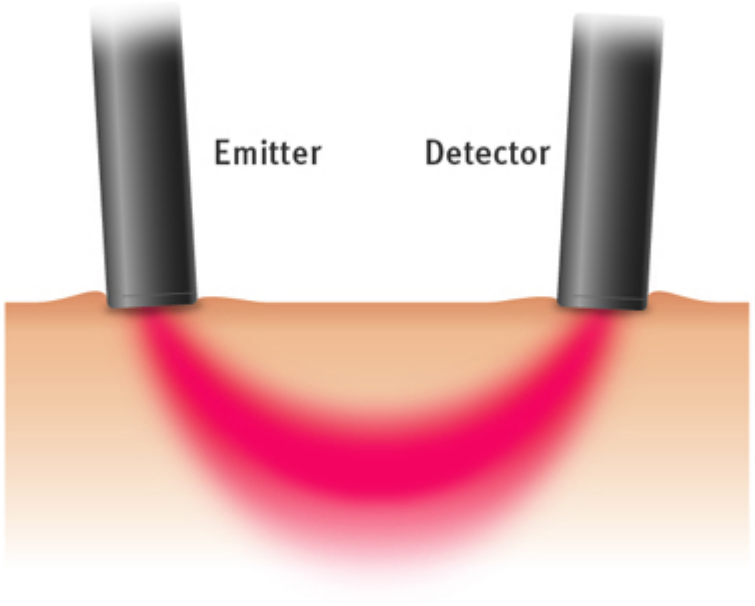
Real-Time Task: Adapting Difficulty Levels in Learning Task



Found both increased accuracy and playing speed.

functional Near Infrared Spectroscopy
fNIRS





Detects levels of oxy and deoxy-hemoglobin
Indicating levels of cognitive workload

Beste F Yuksel[1], Kurt B Oleson[1], Lane Harrison[1,2], Evan M Peck[3], Daniel Afergan[1,4], Remco Chang[1] and Robert JK Jacob[1]

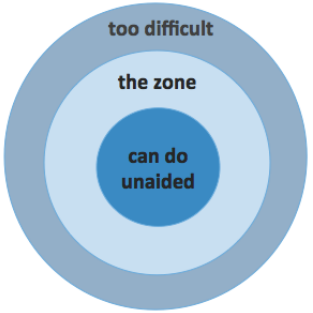
[1]Department of Computer Science, Tufts University, Medford MA

[2]Department of Computer Science, Worcester Polytechnic Institute, Worcester MA

[3]Department of Computer Science, Bucknell University, Lewisburg PA

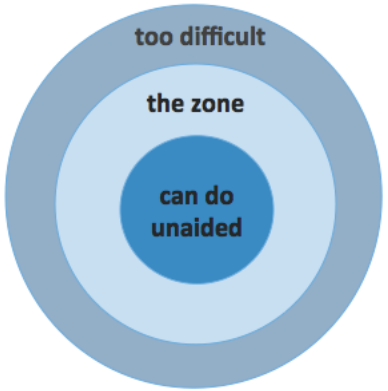
[4]Google Inc., Mountain View CA

Finding the Zone



- This is just one example of an active field
- Brain science interacting with AI and learning science may in future be able to help improve learning significantly.

Erik Andersen
Cornell U



A New Framework for Representing Knowledge for Problem Progression

Problem: state of the art for suggesting next question usually represents knowledge along only one dimension.

Solution: a more expressive, yet still simple, representation based on partial order graphs.

Advantages: can more richly represent the zone of proximal development, and can compare learning strategies.

First: Univariate Representation

A — 1 bit addition without a Carry

B — 1 bit addition with a Carry

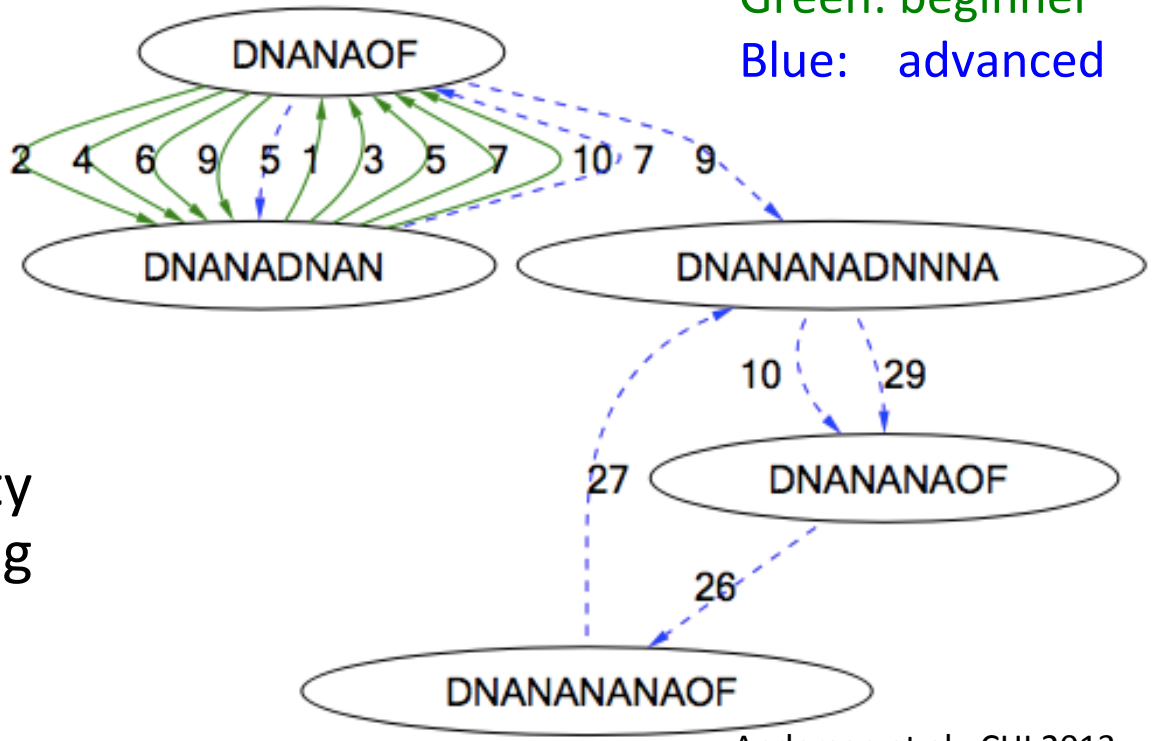
C — Writing a Carry

D — Bringing down a final carry

15+18

93+15

Shines Light on Ordering of Examples



Can express:

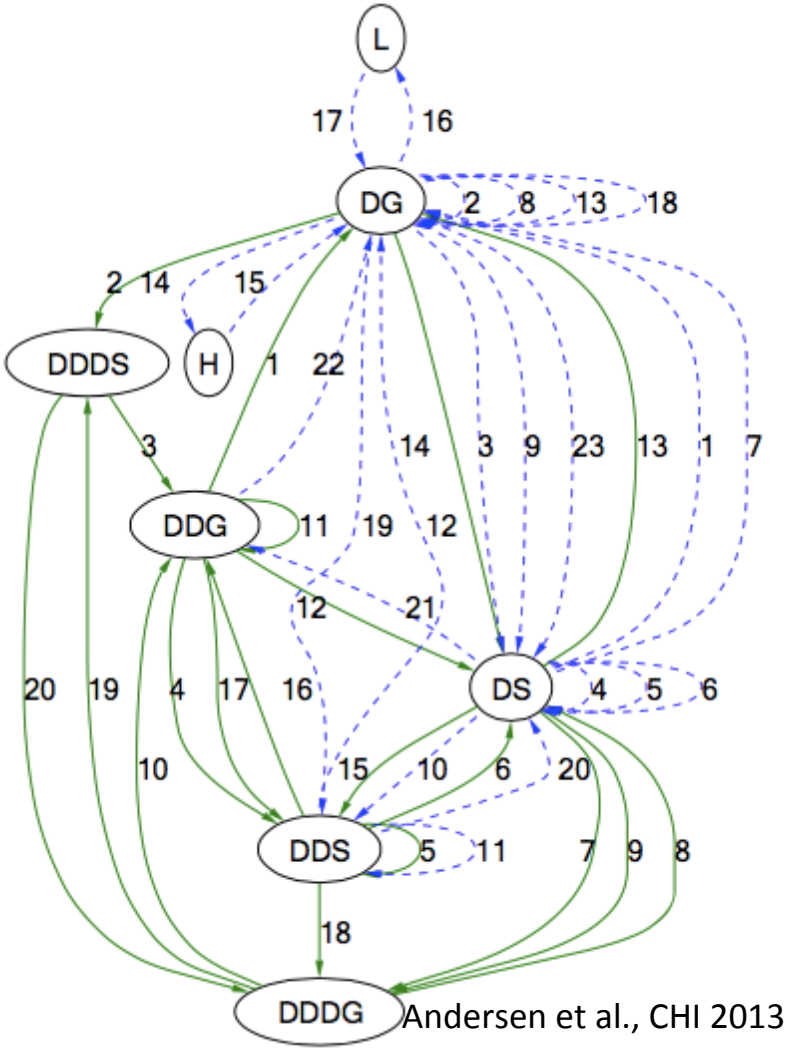
- Unintended difficulty in sequence ordering
- Gaps

Andersen et al., CHI 2013

Comparing Two Textbooks' Progressions

Green reaches more difficult problems than blue

Blue omits key problem types



Andersen et al., CHI 2013

More Complex Representation Example

S1:	私	の	先生	
	I	of	teacher	
	" my teacher "			
Templates:	(– の)			
S2:	私	の	先生	は	忙しい
	I	of	teacher	(topic)	busy
	" my teacher is busy "				
Templates:	(– の) (– は)				
S3:	私	の	先生	の	名前
	I	of	teacher	of	name
	" my teacher's name "				
Templates:	(– の) (– の)				

S2 is harder than S1 since it has 2 distinct templates.

More Complex Representation Example

S1:	私	の	先生		
	I	of	teacher		
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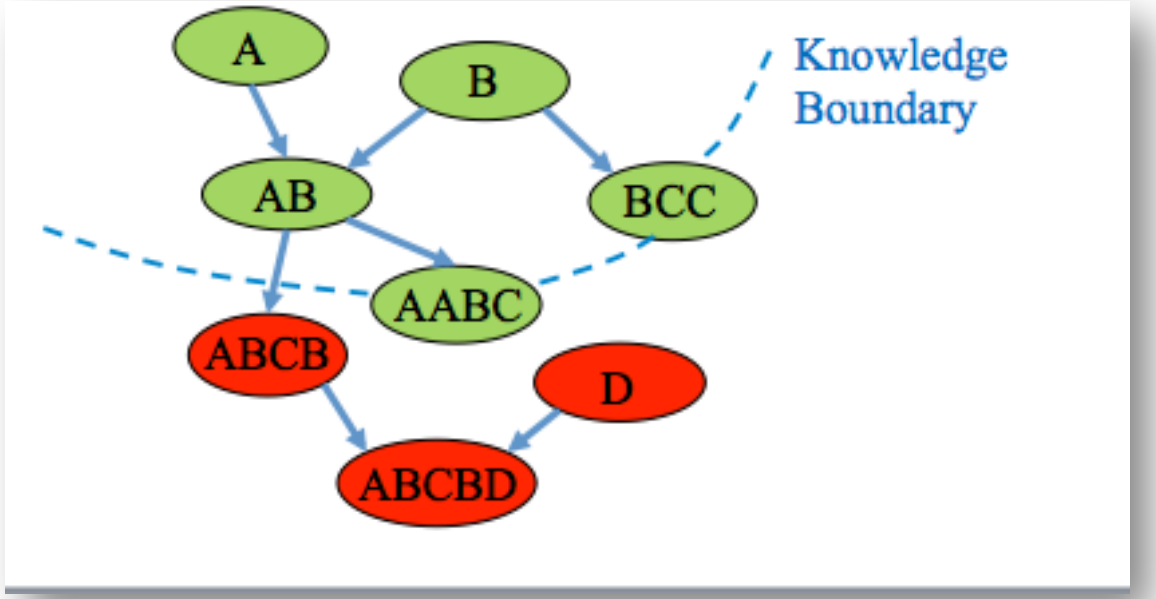
	I	of	teacher	of	name
	“ my teacher’s name ”				
Templates:	(– の) (– の)				

S2 is harder than S1 since it has 2 distinct templates.

S3 is harder than S1 but easier than S2 since the templates repeat.

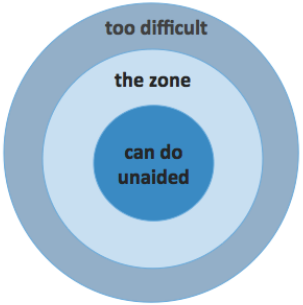
Multivariate Case:
Build This Representation Into A Partial Order

Knowledge boundary: the hardest problems a student can currently solve.

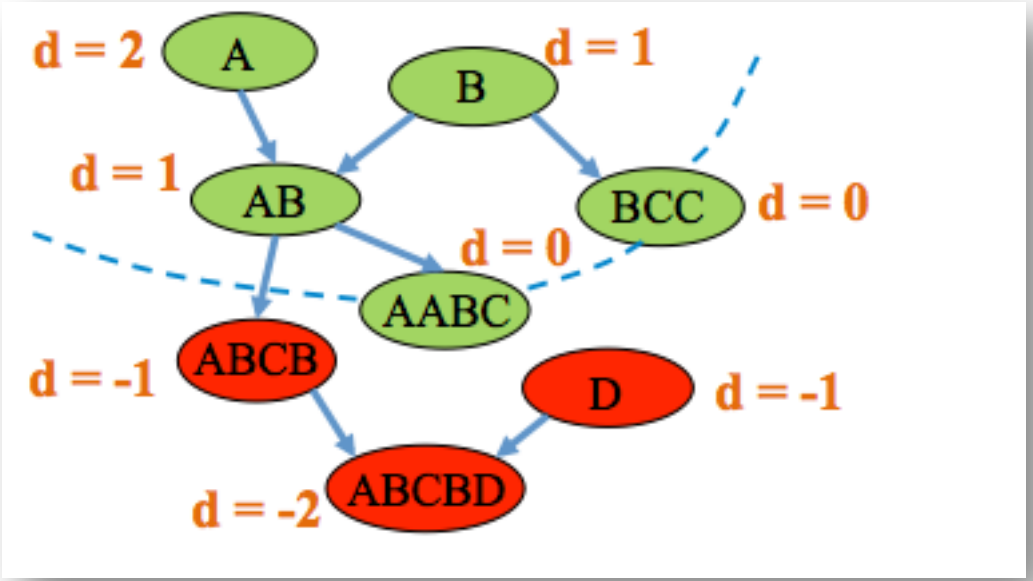


Wang, He, & Andersen, CHI 2016

Knowledge boundary distance



Idea: use *distance* from the boundary to predict problem difficulty for a particular learner.



Can control distance from the zone.

Wang, He, & Andersen, CHI 2016

Example: Learning Japanese grammar

Asks learners if they understand each sentence.

Marks the partial ordering graph accordingly.

Predicts learners' perceptions of difficulty *without data*.

Wang, He, & Andersen, CHI 2016

Comparing Lesson Plans

Can characterize problems as

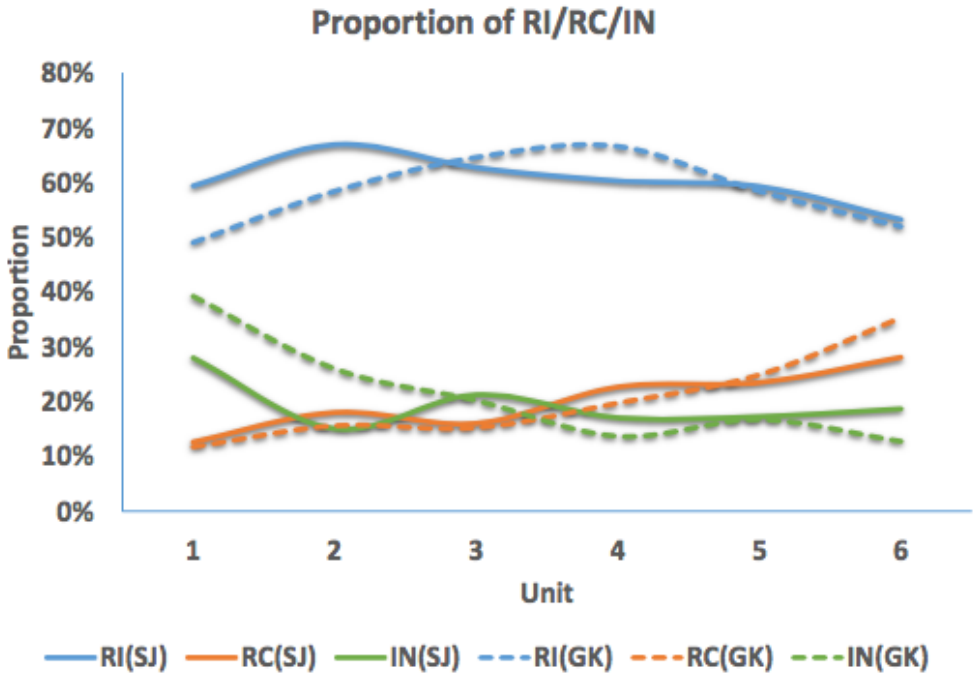
Introduction

Reinforcement

Recombination

(It is reinforcement if it is on the red side of the learner graph boundary.)

Compared 2 textbooks: similarity in pace and composition of problems.



Wang, He, & Andersen, CHI 2016

Word Problems: Currently Boring and Difficult

Suzy is ten years older than Billy, and next year she will be twice as old as Billy. How old is Suzy now?

You attended high school for 4 years. Each year you bought 7 new textbooks. How many textbooks do you have at home now?

Polozov, Oleksandr, et al. IJCAI 2015

Alternative:
Make Word Problems Into *Stories*

Knight Alice has 30 chalices. Dragon Elliot has 9 chalices. Alice slays the dragon, and takes his chalices. How many chalices does she have now?

Polozov et al., IJCAI 2015.

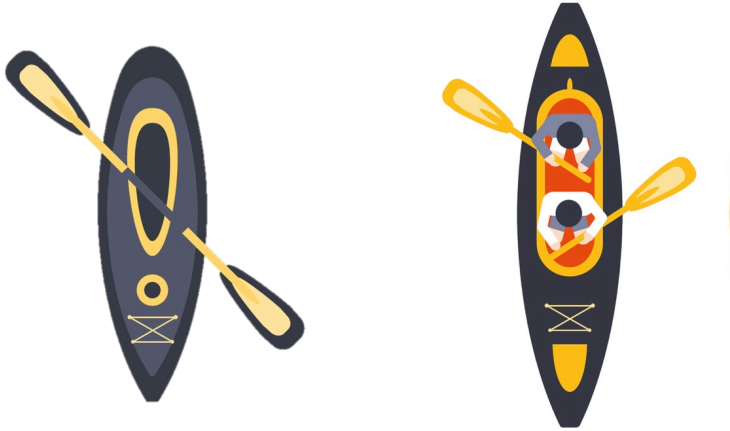
Word Problems as Stories Allows Mastery

- Let kids choose the characters and the themes
  - Fantasy, Science Fiction, Wizardry
- Use templates and constraint solvers to enforce logical relations
- Add in Discourse Tropes and Co-reference Resolution
- Students love this game-like version of work problems, and many play for hours and thus achieve mastery.

Polozov, Oleksandr, et al. IJCAI 2015

Opportunities for AI to Intersect with Learning

Zone of Proximal Development



Peer Learning

Learning With Other Students

Hundreds of research papers show the value of peer learning.

Peers remember what it’s like to not understand

The way to really learn something is to teach it to someone else

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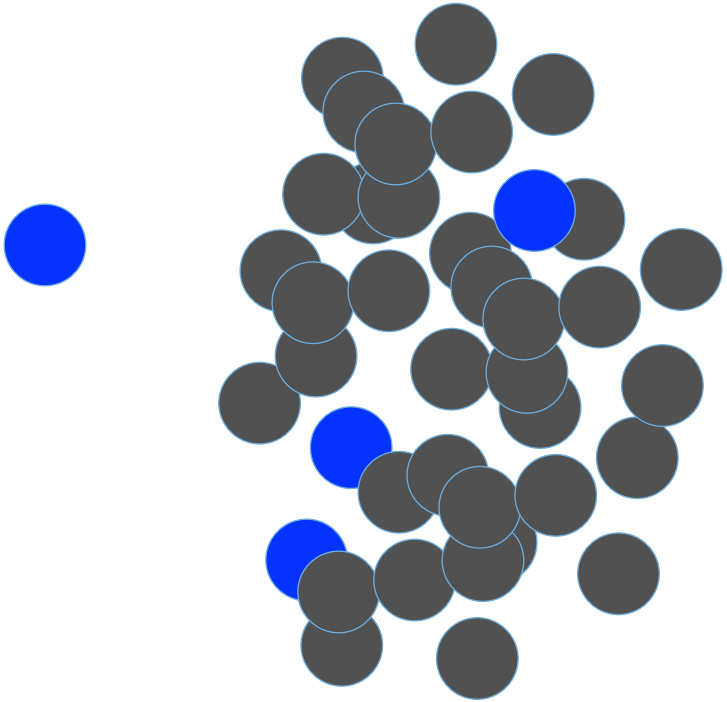
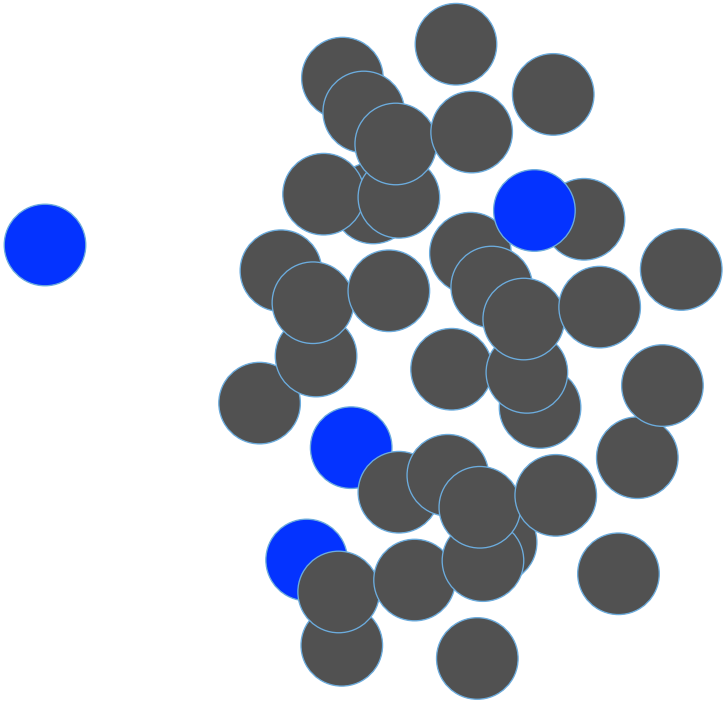
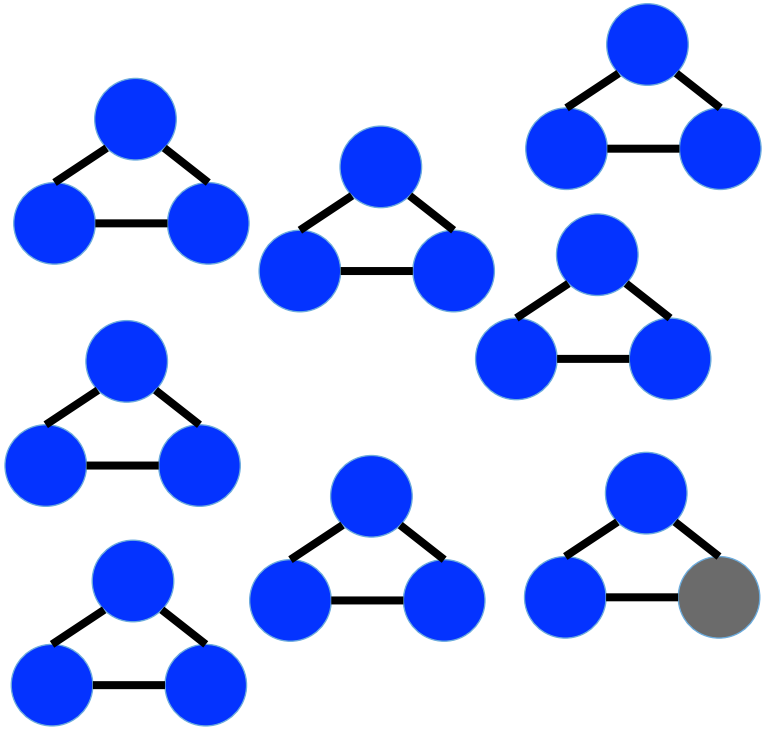
Large lecture / forum



Large lecture / forum



Small group discussions



Goal: *Structured* Peer Learning

- Online, the conversations may wander, or become incorrect.
- For many learning contexts, want discussion structured around goals
  - Strategies developed in the 1990's for how to do this in person
    - Example: students in small group are responsible for everyone's success
    - The lowest score on the quiz is everyone's score
- There are opportunities for AI to better facilitate structured peer learning online

MOOCChat: Can We Design Small Group Discussions to Improve Learning Online?

- Hypothesis:
  - People working in groups online will get the answers right more often than those working alone.
  - Especially if an incentive is given to work together.

Coetzee, Lim, Fox,, Hartmann, and Hearst, CSCW 2015

Question

With the decline of predators, such as wolves and coyotes, that used to keep the deer population within certain limits, deer have increased in numbers until they cannot feed themselves in the forest alone but must forage on open rangeland in competition with cattle. Thus, in areas where forest borders on rangeland, deer hunting is an essential activity.

This argument would be most seriously weakened if it could be shown that

Choose one of A to E. Please scroll down if your screen does not display all choices.

Possible Answers

A
deer hunters are not concerned about the prosperity of ranchers

B wolves and coyotes do not prey upon deer only

✓ deer and cattle do not eat the same plants

D
deer hunting is popular even in areas where the forest does not border rangeland

E
the deer population may someday be hunted out of existence

Discuss this question until the timer runs out. You may change your answer choice during the discussion.

Discussion

Student 3: I chose C because it seemed to clash with the statement "deer hunting is an essential activity" more than other statements

Student 1: I don't think the popularity of deer hunting is the issue.

Student 3: Right, it's whether it's essential. If the deer and cattle don't eat the same plants, then deer hutning isn't essential to preserve the rangeland for the cattle.

Student 1: That's how I see it.

Me: Actually, I did not understand the question until now. Whoops.

Me: I actually do believe it's C.

Student 3: Awesome!

Me: That was easy!

Student 3: We all agree so let's hope for the bonus :)

Send

Student List

Student 1 C Flag This Student

Student 2 D Flag This Student

Student 3 C Flag This Student

Your first choice was D
Your final choice is C

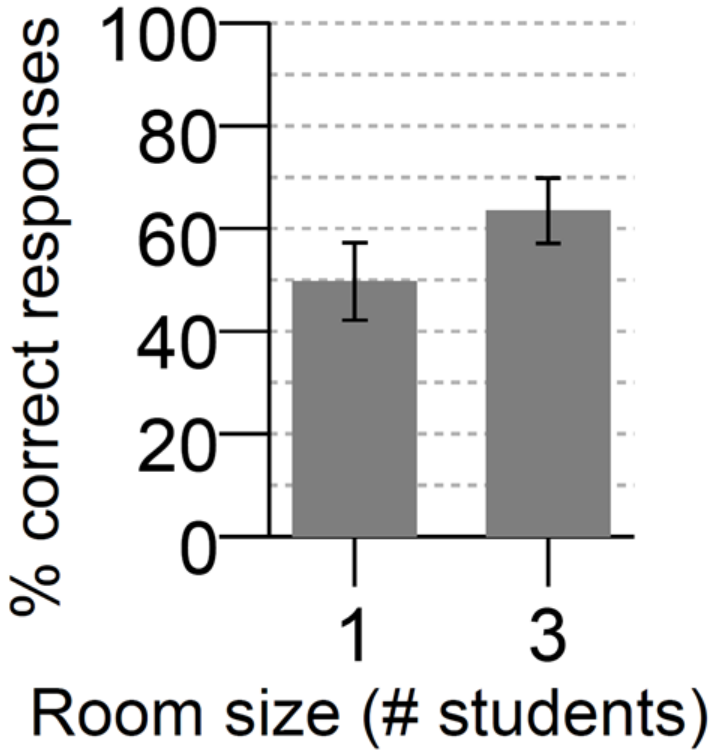
Timer
03 : 10

Quit Discussion

Results: Discussion Improves Results

- Higher % of correct final responses for workers in groups (Fisher's test, $p < 0.01$)

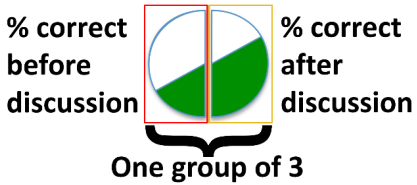
- Bonus incentive also improved results



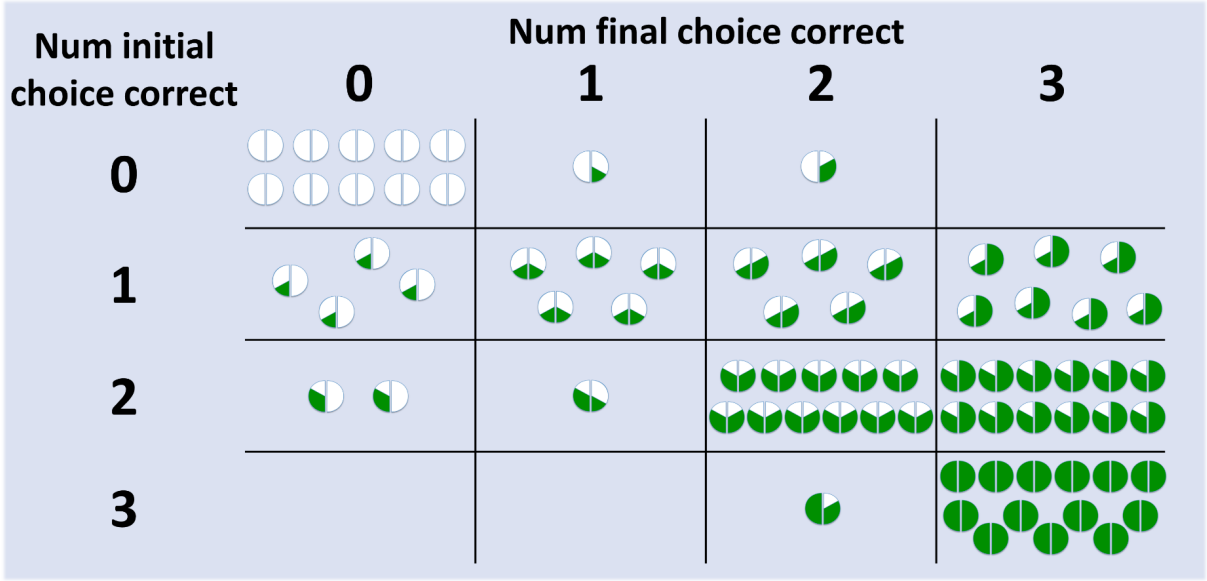
Sample Discussion

- Student 2: I think E is the right answer
- Student 1: Hi, I think E is right, too
- Student 3: Hi! This seems to be a nurture vs nature question.
- Student 3: Can scent be learned, or only at birth?
- Student 2: Yeah, but answer A supports the author's conclusion
- Student 1: I felt that about A too
- Student 2: But the question was, which statement would weaken the author's conclusion
- Student 3: So I choose A, showing that scent can be learned at not only AT BIRTH.
- Student 2: That's why I think E is right
- Student 3: Are you real, or fake?
- Student 2: real

All You Need is 1 Correct



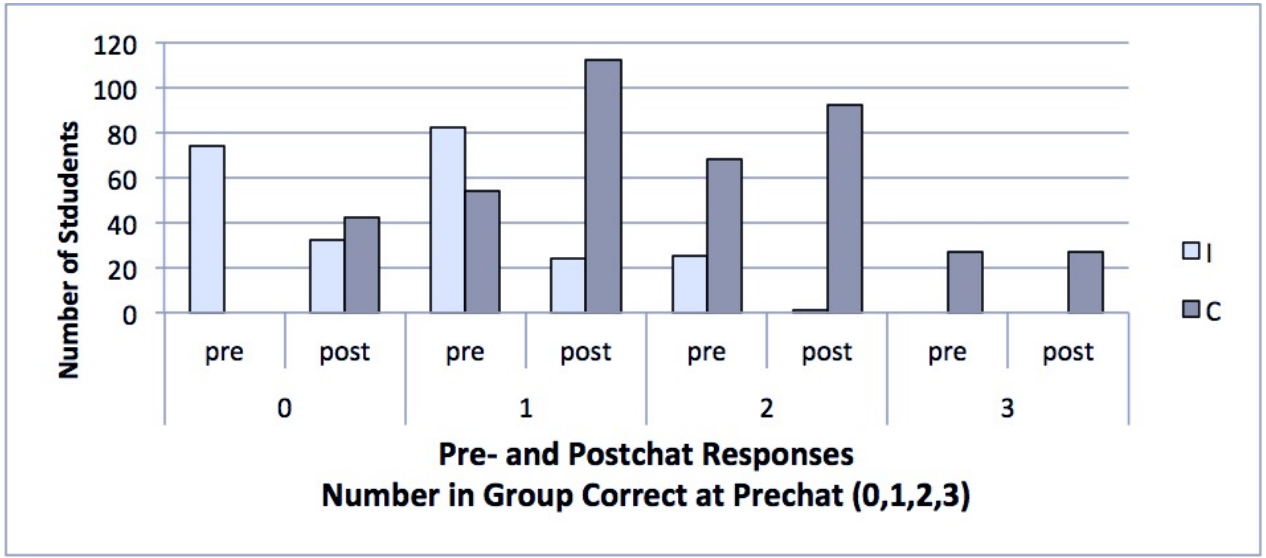
Groups with at least one correct student are more likely to reach the correct answer.



MOOCHAT with Students

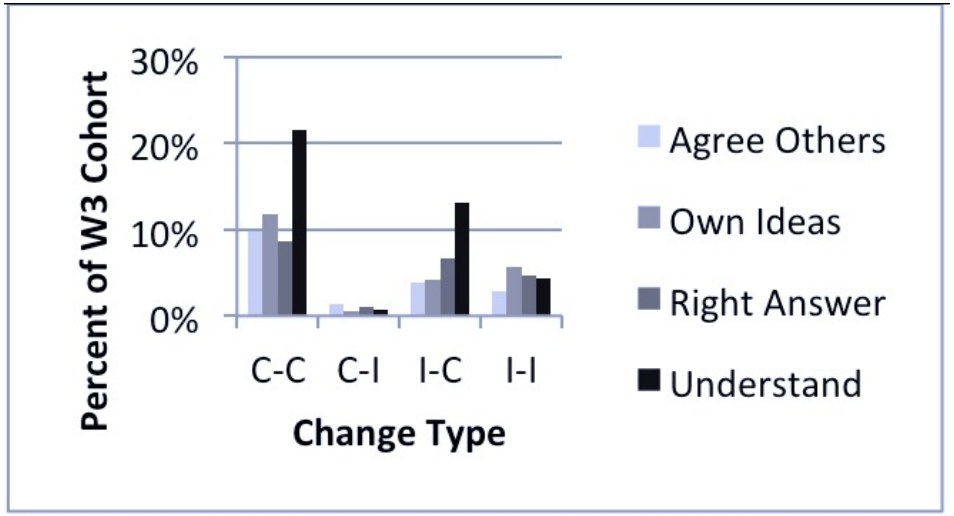
- Carl Reidsema, University of Queensland
- Intro engineering course with online component and >1000 students
- Reproduced our results

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA



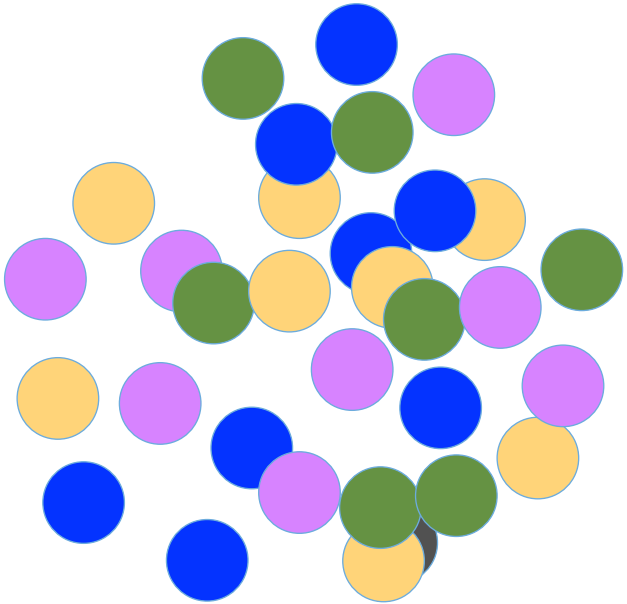
MOOCHAT with students

- And found learning gains
  - Groups that aimed for understanding ended up with better results for group members
  - If the problems were in the zone of proximal development, the chats correlated with better exam results
  - If the problems were too difficult, the chats did not necessarily help

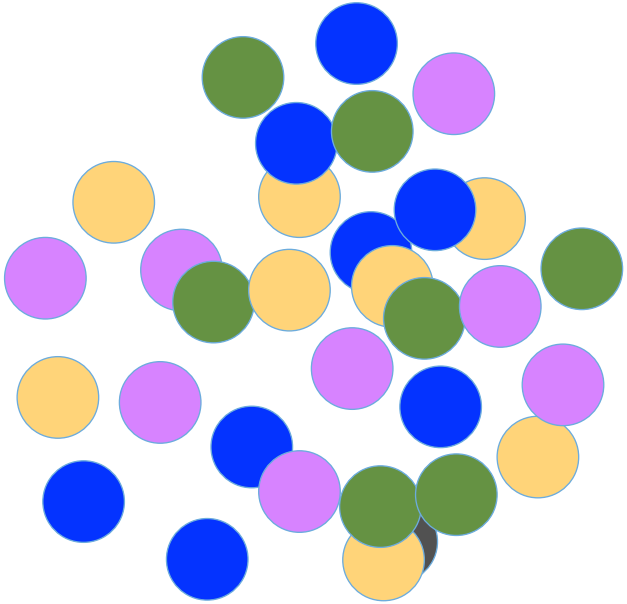


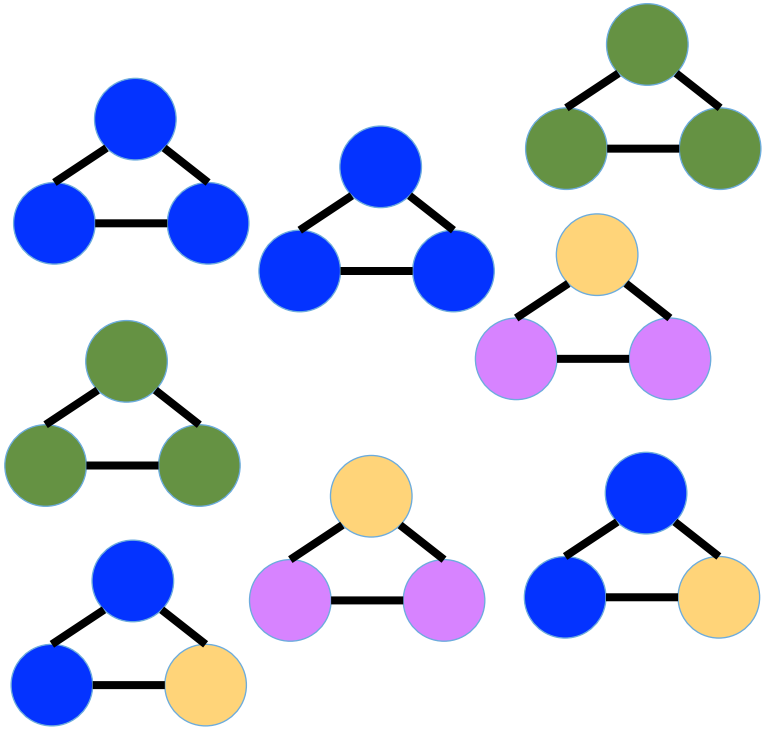
W3 Medium concept questions

Idea: dynamically group students online based on their initial answers



Idea: dynamically group students online based on their initial answers





Peer Learning: Where AI Can Help

- Incent students to help one another
- Make sure students have on-topic conversations
- Steer the conversations if they get off topic or go too far wrong
- Determine who to put into the same virtual groups based on initial preconceptions based on initial choices or statements.
- Determine which groups should have a live TA inserted in real time and for how long.

Outline

Why We Need to **Accelerate** Learning

MOOCs, Active Learning, and Intelligent Tutoring Systems

Opportunities for AI to Improve Learning Tools

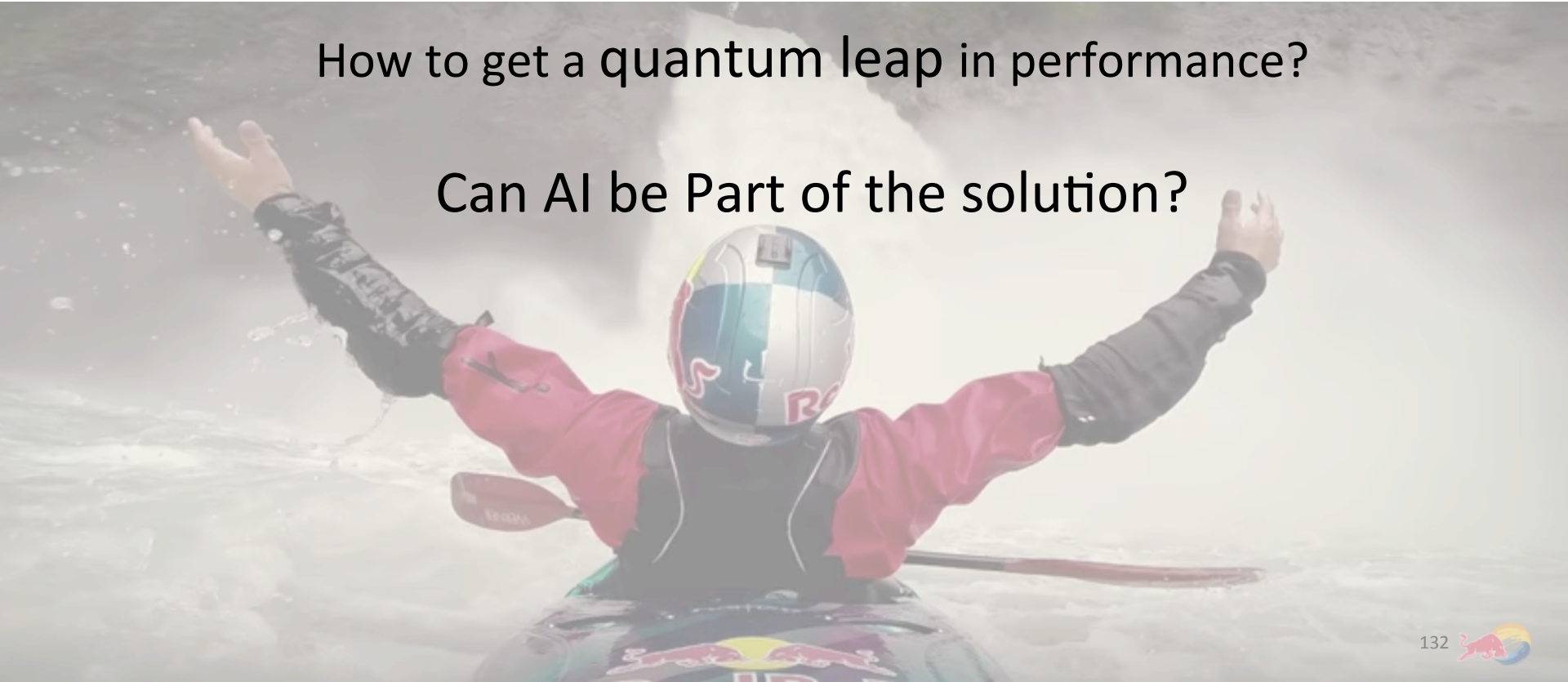
Caveats, a Conundrum, and Conclusions

The Argument

- Although for decades technology has been changing the employment landscape, the change seems to be accelerating today.
- **One way** to address this is to help people help themselves by improving our methods for teaching and learning.
- **One method** for improving our teaching and learning is for AI to play a bigger role than it has to date.

MOONSHOT: Accelerate Learning

Moonshot: Accelerate Learning



How to get a quantum leap in performance?

Can AI be Part of the solution?

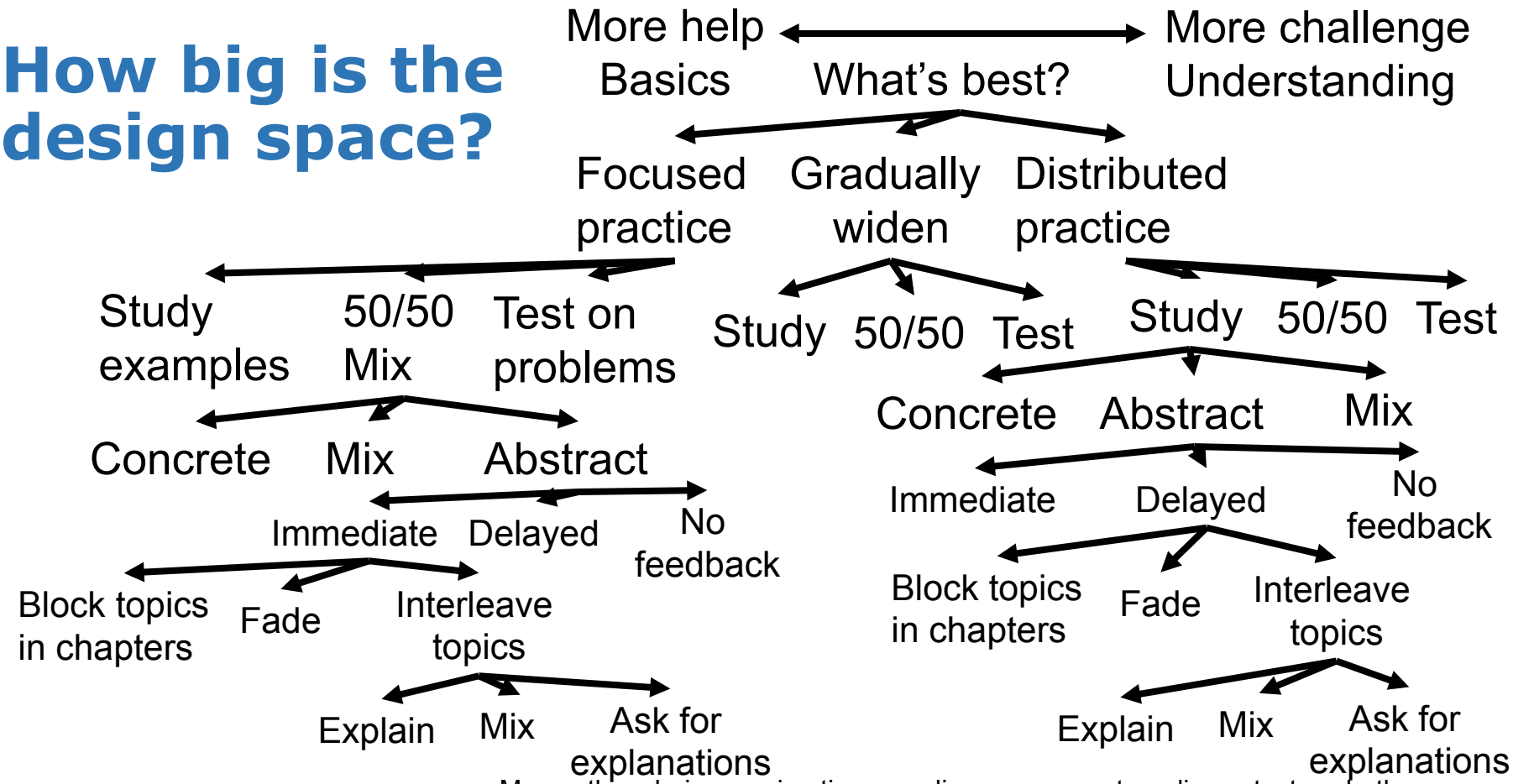
Ken Koedinger

What do we know about what works?

Spaced practice > massed (Pashler)
But massed sometimes better (Pavlik)
Retrieval practice > example study (Roediger)
But worked examples > pure practice (Sweller)
Direct instruction > discovery learning (Klahr)
But active learning > lecture (PNAS 2016)
Other debates:

- Is explaining good or bad? (Chi v Williams)
- Interleaving vs blocking? (Rohrer v Carvalho)

How big is the design space?



Many other choices: animations vs. diagrams vs. not, audio vs. text vs. both, …

$>3^{15*2}$ = 205 trillion options!

Koedinger, Booth, Klahr. Instructional Complexity and the Science to Constrain It. *Science, 2013*

Ken Koedinger

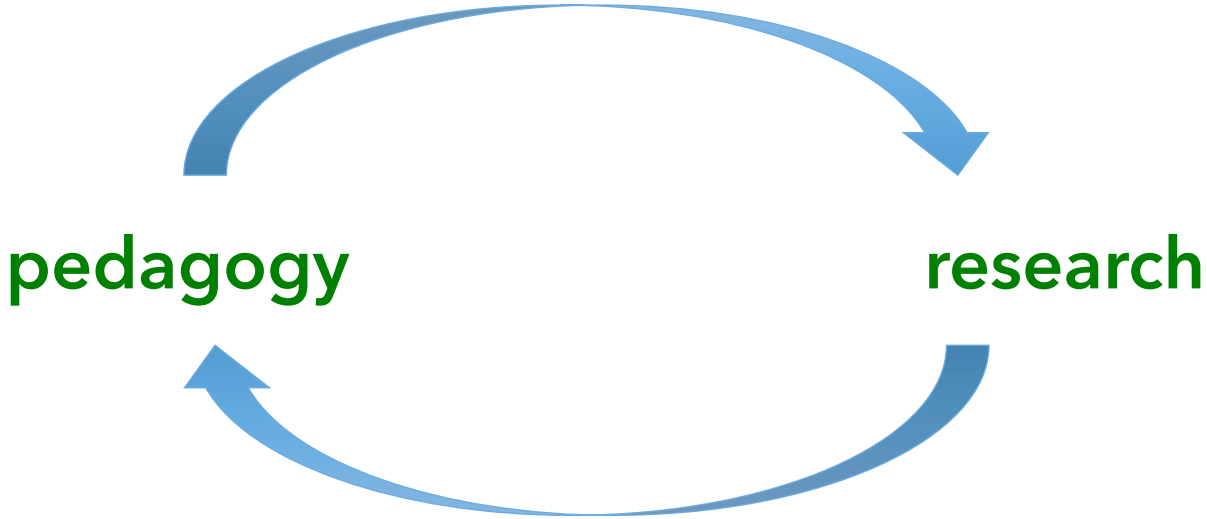
Every school and university should be an educational research lab!

Technology-Enhanced Learning: Best Practices and Data Sharing in Higher Education

By the Global Learning Council members and its Best Practices Working Group
April 2016

Koedinger, Learning@Scale Keynote 2016

Every Course is an Opportunity to Advance Understanding



Five years ago, Marketplace explored how machines, robots and software algorithms were increasingly entering the workforce in our series "Robots Ate My Job." Now, we're looking at what humans can do about it with a new journey to find robot-proof jobs.

- Ethan Miller/Getty Images

Tom Kalil

“'How could we take advances in artificial intelligence and … reduce the time for a non-college educated worker to gain a skill that is a ticket to the middle class?'"

Government should work with the brightest minds and companies to invest ***massively*** in new ways to help workers adapt to a workforce that increasingly includes algorithms and machines doing the work humans used to.

Tom Kalil

US Defense Budget: $71B
US Labor Budget: $4B
(2016)

E-ARPA

CONUNDRUM:

If AI Improves Learning via Automation, Does this Add to the Job Disruption Problem?

Change, Not Elimination

Learning requires people!

- Willpower
- Encouragement
- Cohort
- Expert Advice
- …

We Want to Accelerate Human Learning Beyond What Is Possible Today

We don’t know how to reach 2-sigma goal.

Automation and expertise together might be the key.

Learning:
The Ideal Laboratory for Core AI Problems

- Machine Learning
- Knowledge Representation
- Reasoning
- Natural Language Processing
- Image and Video Analysis
- Cognition
- Neuro-X

Working together we might make a difference.

Thank you!

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