CS Research on MOOCs and Online Education

- Amy Bruckman (organizer)
  - Professor of Interactive Computing, Georgia Tech
- Marti Hearst
  - Professor of Computer Science, School of Information, UC Berkeley
- Rob Miller
  - Professor of Computer Science and Engineering, Massachusetts Institute of Technology
- Scott Klemmer
  - Associate Professor, Cognitive Science and Computer Science & Engineering

Computer Science Research on Higher Education?

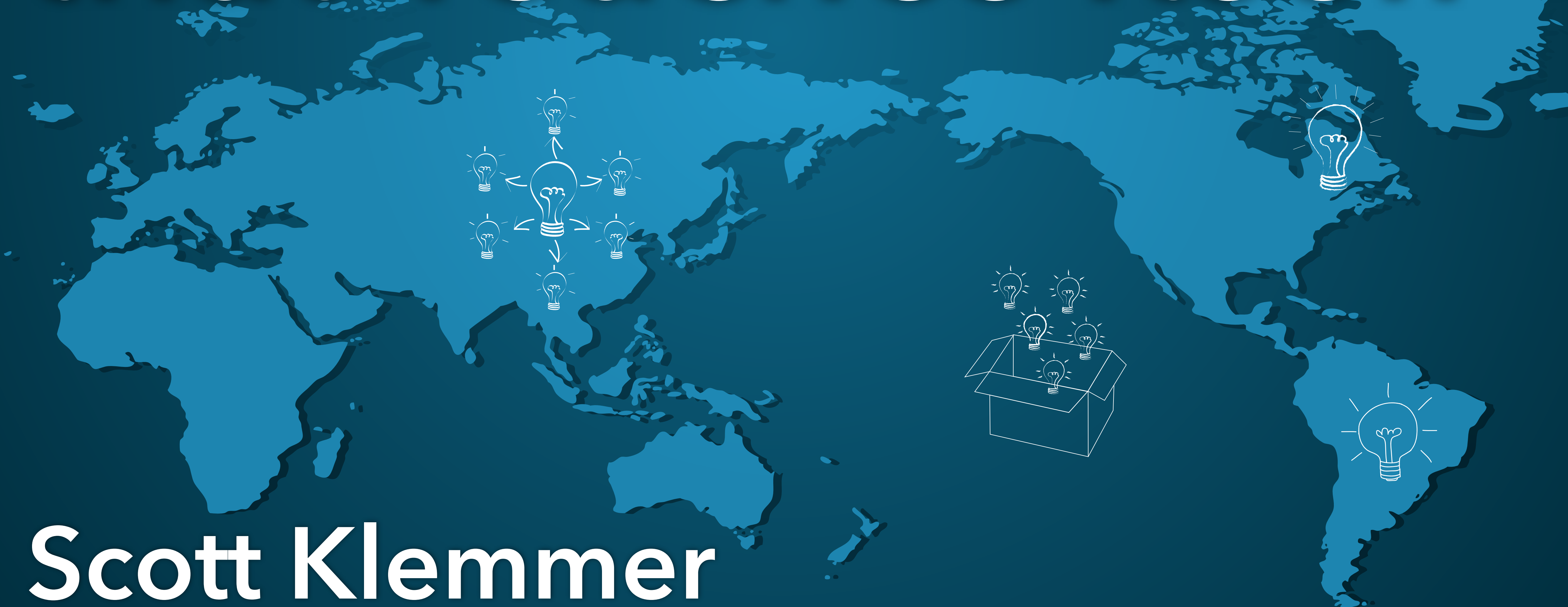
- Future of online education is not just about trying things out
  - Research needed
  - Interdisciplinary
    - Industry
    - Schools of education
    - Schools of computer science
- How do we support this new interdisciplinary practice?

Intriguing Research Challenges

- Three strong examples of CS research on online education
- Discussion of the challenges
- Discuss both MOOCs and distance ed
  - Make clear which issues refer to which

- Thanks to Andy, Greg, and Brent

Designing a World that Teaches Itself



Scott Klemmer

Cognitive Science + Computer Science & Engineering

UC San Diego + Stanford

CHALLENGE & OPPORTUNITY

Design at Large

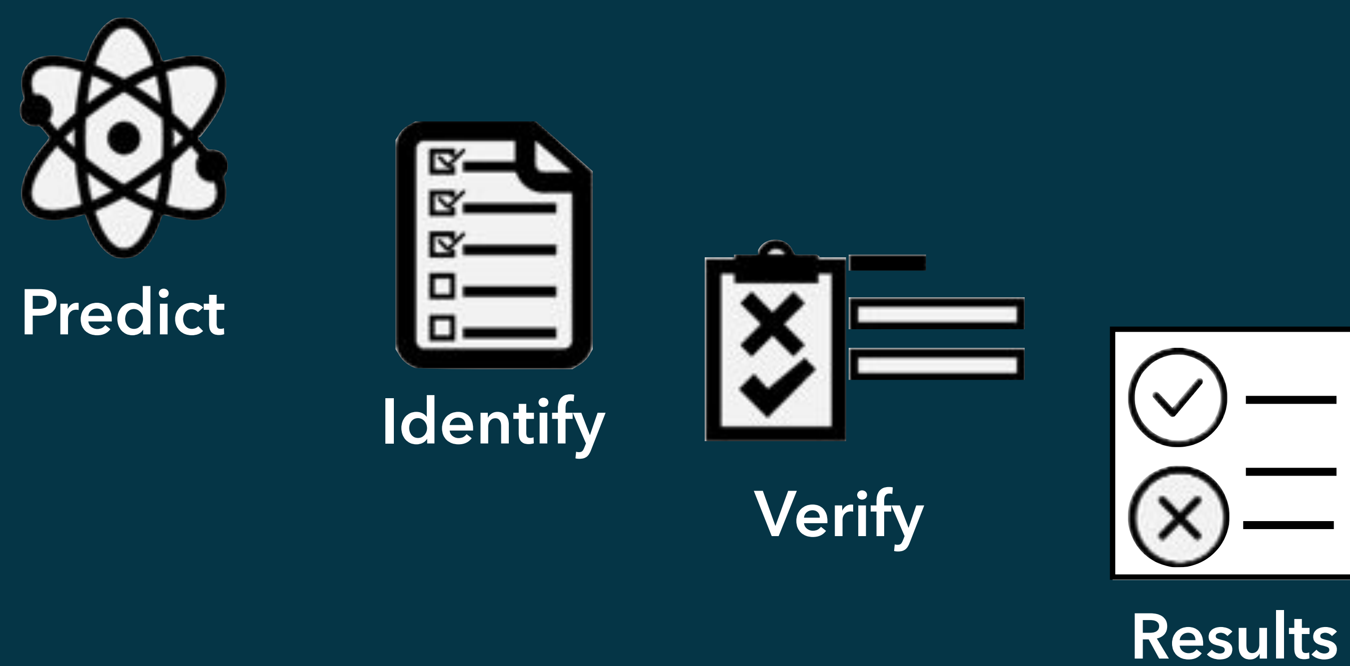

Zappos
Zappos
loft→LOFT

RESEARCH EXAMPLES

peer assessment

small-group discussions

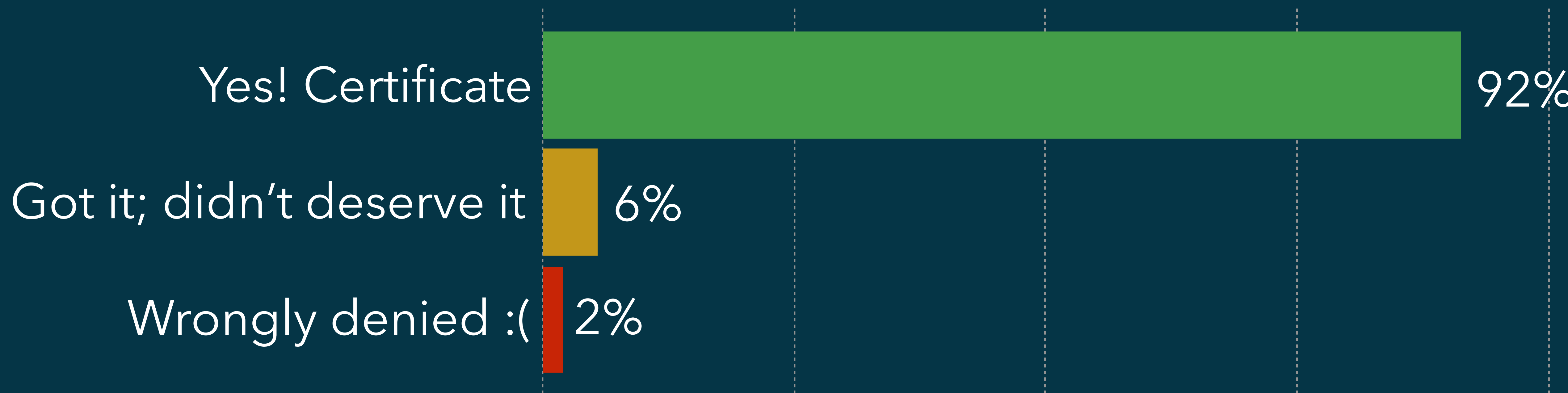
richer feedback



machine+peer learning

AT LARGE…

Peer assessment



Peer and Self Assessment in Massive Online Classes, Kulkarni *et al.*, TOCHI 2013

AT LARGE…

Peer assessment in 100+ classes

Human-computer Interaction
Design

Programming in Python
Code

Introduction to Philosophy
Essays

Teaching character
Management

Child Nutrition
Recipes

Social Psychology
Essays

Constitutional law
Arguments

World Music
Music

Peer and Self Assessment in Massive Online Classes, Kulkarni *et al.*, TOCHI 2013

FORTUNE COOKIES

Qualitative, personalized feedback

- Peers can recognize errors from a list of patterns, even if they can't articulate them
- Most errors are variations on a theme

+ "...because ______________________"

Peer and Self Assessment in Massive Online Classes, Kulkarni *et al.*, TOCHI 2013

Alone Together?

LEVERAGING DIVERSE EXPERIENCES

Small groups in massive classes

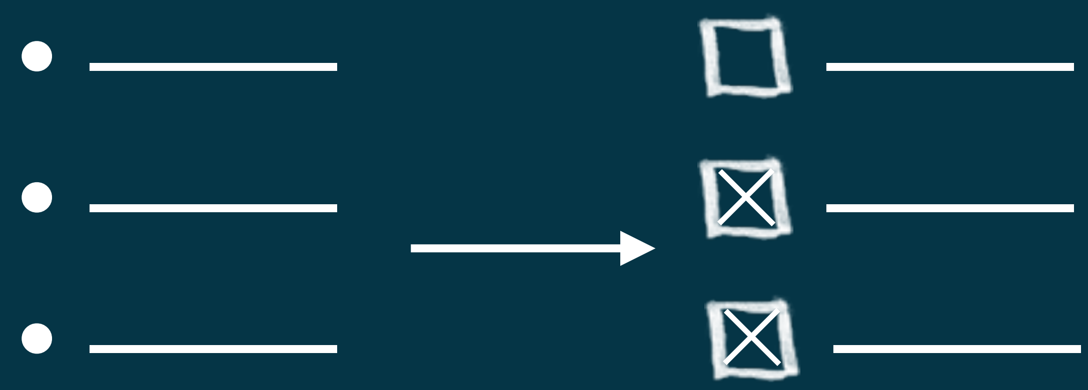
"It was like a mini-UN. We had an Australian currently residing in Dubai, an Afghan, a Romanian, an Indian & myself (a Pakistani)."

Making Distance Matter with Small Groups in Massive Classes, Kulkarni *et al.*, in submission

Creating Micro-Experts

- richer semantics increase quality

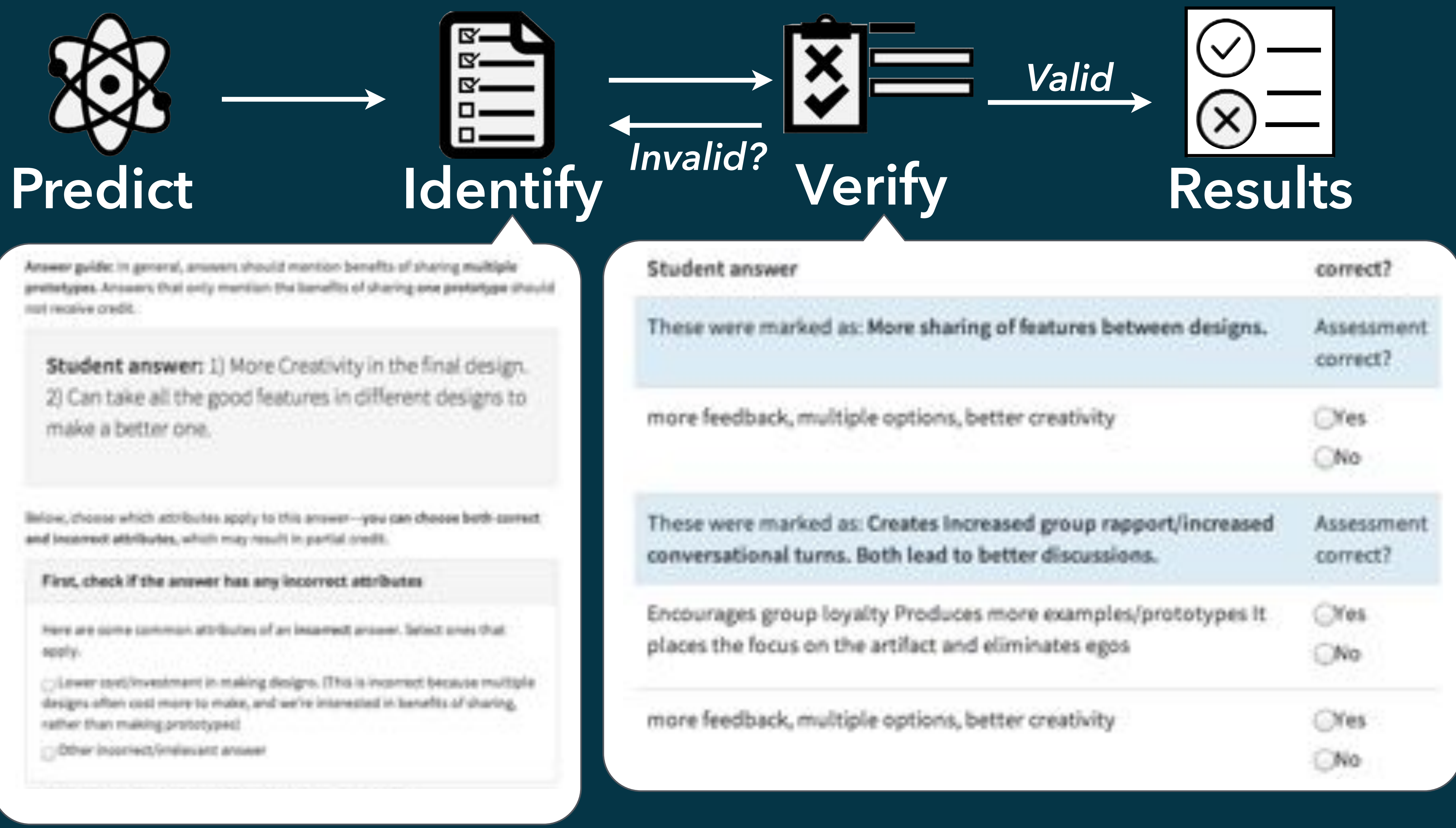
from scores   to labels



Scaling Short-answer Grading by Combining Peer Assessment with Algorithmic Scoring, Kulkarni, Socher, Bernstein, & Klemmer, Learning at Scale, 2014

IDENTIFY-VERIFY

Machines modulate peer grading



Scaling Short-answer Grading by Combining Peer Assessment with Algorithmic Scoring, Kulkarni, Socher, Bernstein, & Klemmer, Learning at Scale, 2014

CS RESEARCH OPPORTUNITY

- Build practical theory with real-world experiments
- Bake pedagogy into software that transforms learning

http://d.ucsd.edu/peer

"Nothing is as practical as a good theory"

"The best way to understand something is to try and change it"

–Kurt Lewin

DESIGN AT LARGE

- Build practical theory with real-world experiments
- Bake that theory into software that transforms <X>

Real experiments are critical

We Need to Do These 3 Things

- Insure that learners understand their role in experiments they opt in to
  Good design is key, and nuanced
- Insuring broad research access to conducting experiments, evaluating data, & open science
  Chairs: you have an important role here
- Few current CS curricula don't teach experimental design. More should.
  Especially in data/HCI/learning tracks

http://cs303.stanford.edu

We Have Resources for You

- Open-source platforms with analytics, course materials, instructor resources, & graduating students :)

http://d.ucsd.edu/peer

The Big Research Opportunity

- Tomorrow's online class won't look like today's (I hope)

scale <u>personalized</u> mastery-learning experiences?

http://d.ucsd.edu/peer

Why CS?

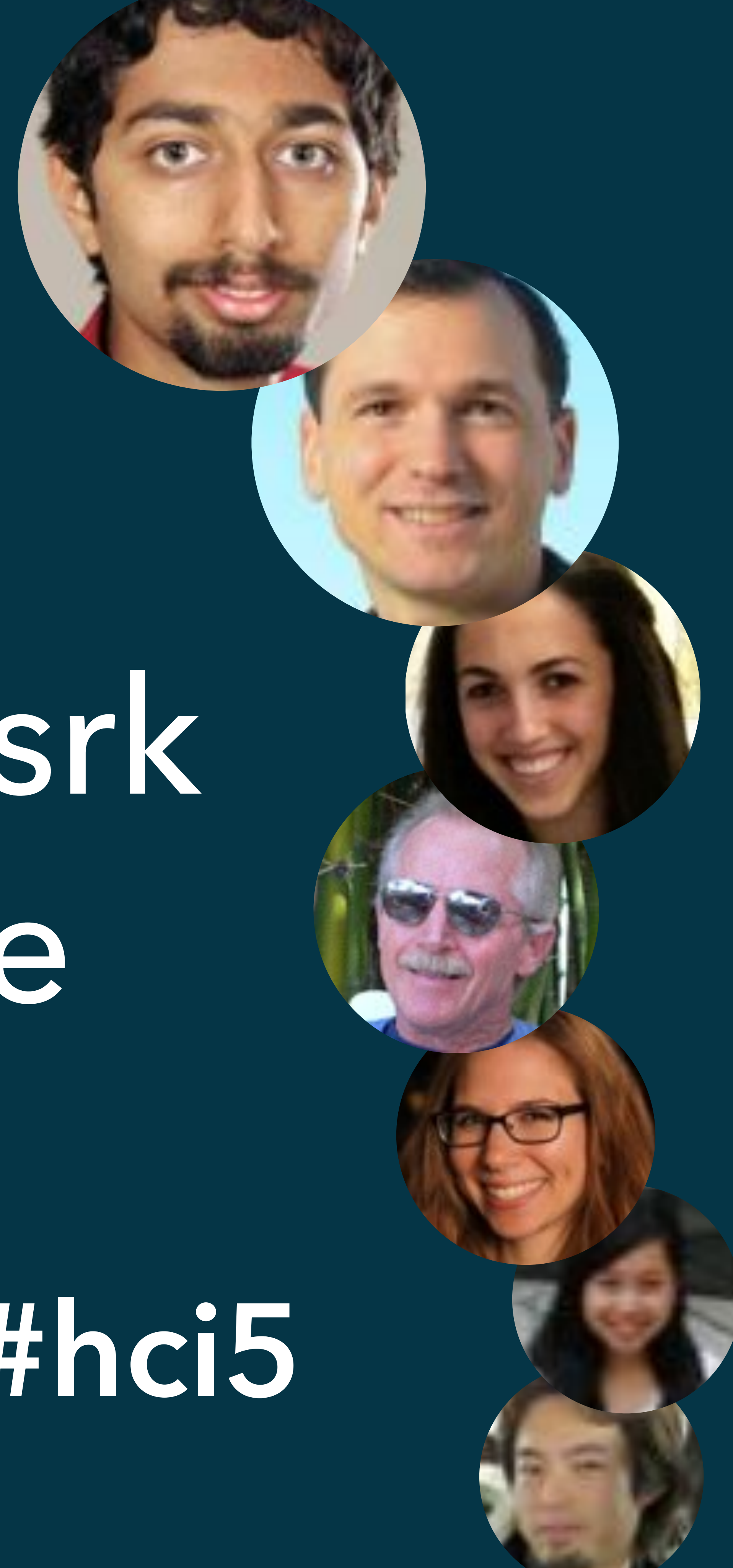
- The scientific opportunities are tremendous
- Concrete problems are a great forge for fundamental insights
- A proud history of lifelong learning
- The CS legacy: don't just understand the world, make it a better place

Fred Brooks, *The Computer Scientist as Toolsmith*

with Chinmay Kulkarni
+ many collaborators

http://d.ucsd.edu/srk
@DesignAtLarge

follow student work at #hci5



Online Education with Learnersourcing

Rob Miller
User Interface Design Group
MIT CSAIL

Joint work with Juho Kim, Sarah Weir,
Elena Glassman, Philip Guo, Carrie Cai,
Max Goldman, Phu Nguyen, Rishabh Singh, Jeremy Scott

MIT HUMAN-COMPUTER INTERACTION

MOOCs: a New Scale for Learning

classroom 1:10

lecture 1:100

stadium 1:10,000

- Big problem
  - we're very far from 1-on-1 mastery learning
  - little human feedback, mass production instead of personalization, high attrition rates
- Huge opportunity
  - much faster controlled experimentation & iterative improvement
  - big online crowds can do amazing things by themselves

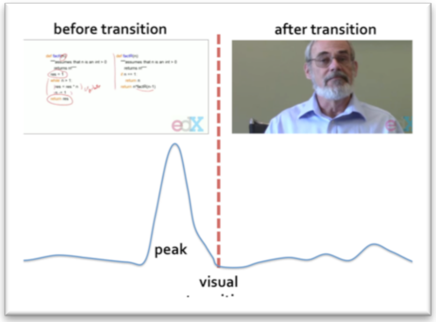
Crowdsourcing vs. Learnersourcing

- Crowdsourcing
  - asking a crowd to do micro-work for problems we can’t solve with software
  - what does the crowd get in return? money, fun, social
- Learnersourcing
  - asking **students** to do micro-work for an online course
  - what do students get in return? **learning** (hopefully)
- Types of learnersourcing
  - active: asking people to do something
  - passive**:** watching what people do and inferring something

- Discussion forums are active learnersourcing
  - and without them, our current MOOCs would utterly fail

A Few Examples from My Group

- Lecture video analytics
  - find bugs and key parts in lecture videos
  - passive learnersourcing



- Peer code review
  - students give feedback to each other
  - active learnersourcing

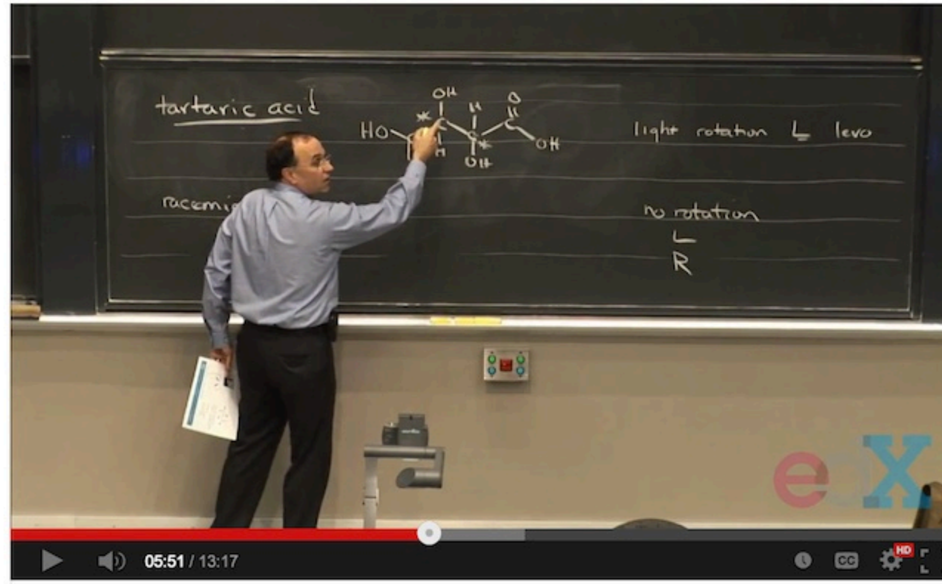
- Solution analytics
  - understand the range of solutions to a coding assignment
  - passive learnersourcing

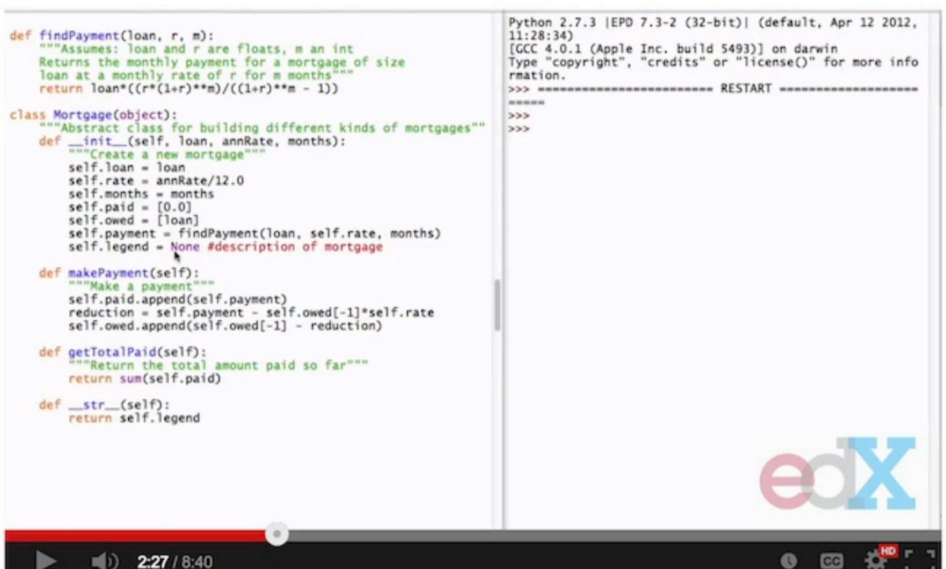
LECTURE VIDEOS

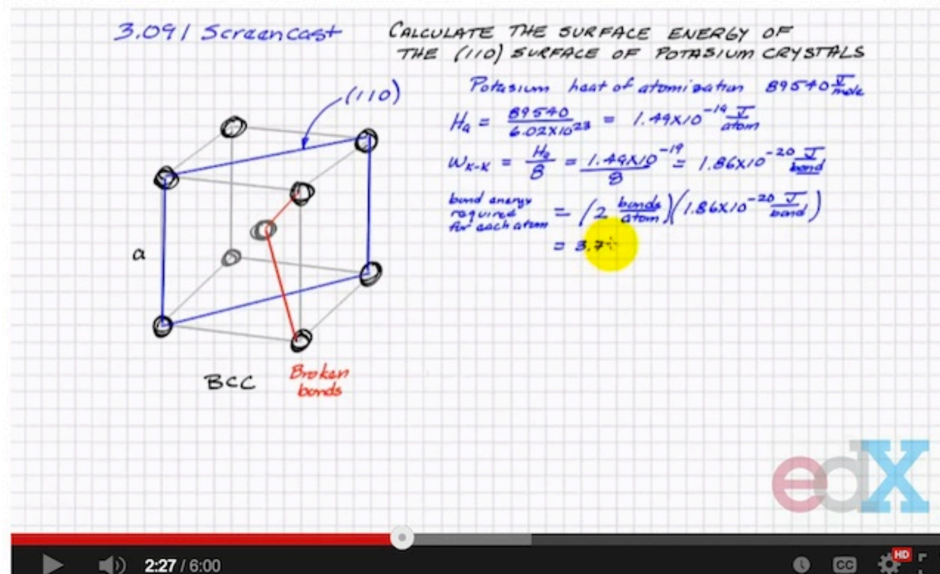
Juho Kim

MIT HUMAN-COMPUTER INTERACTION

MOOC lecture videos







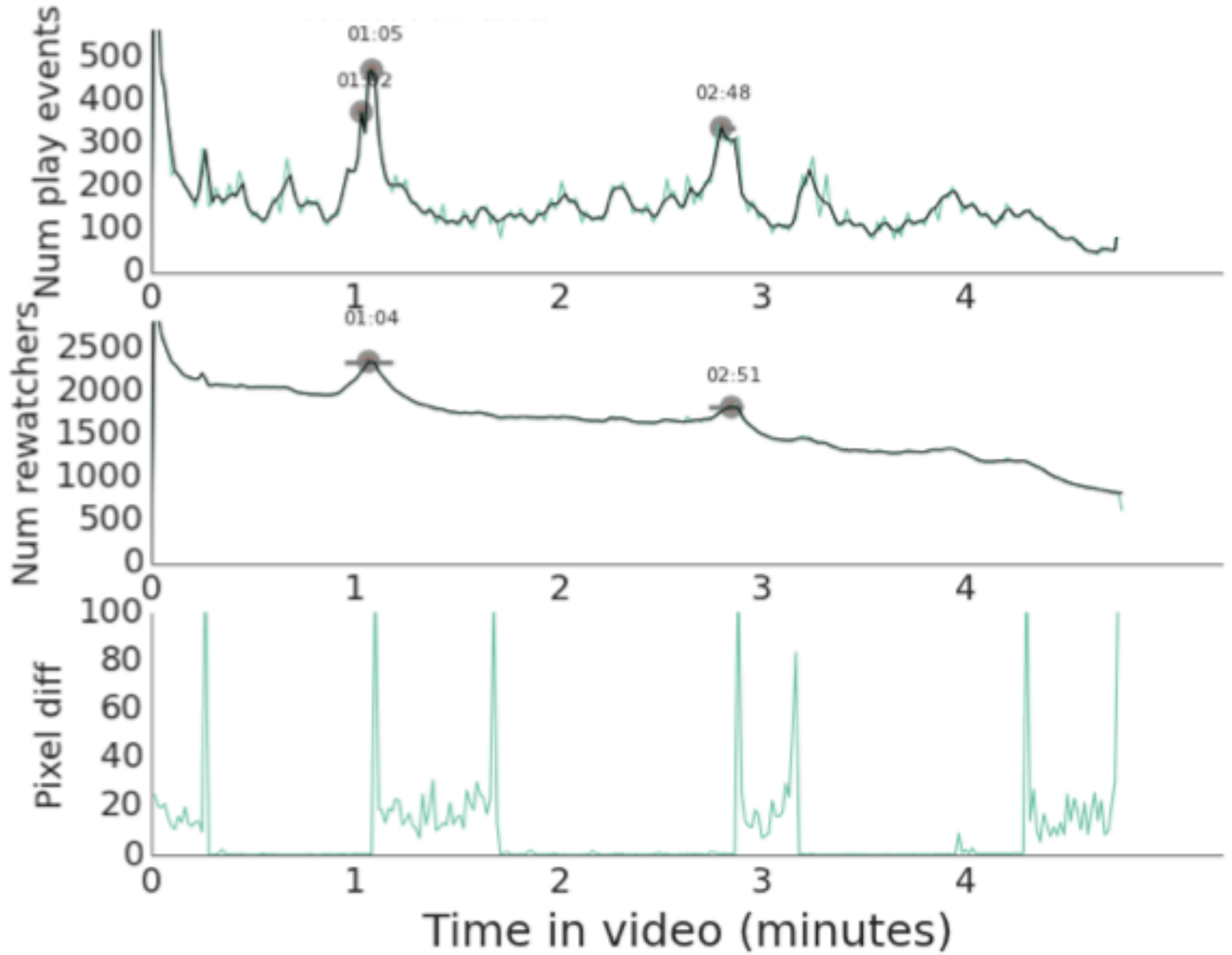
Challenge for instructors/editors

- Don't know how students use lecture videos
  - Confusion
  - "Aha" moments
  - Bored
  - Re-watching important parts

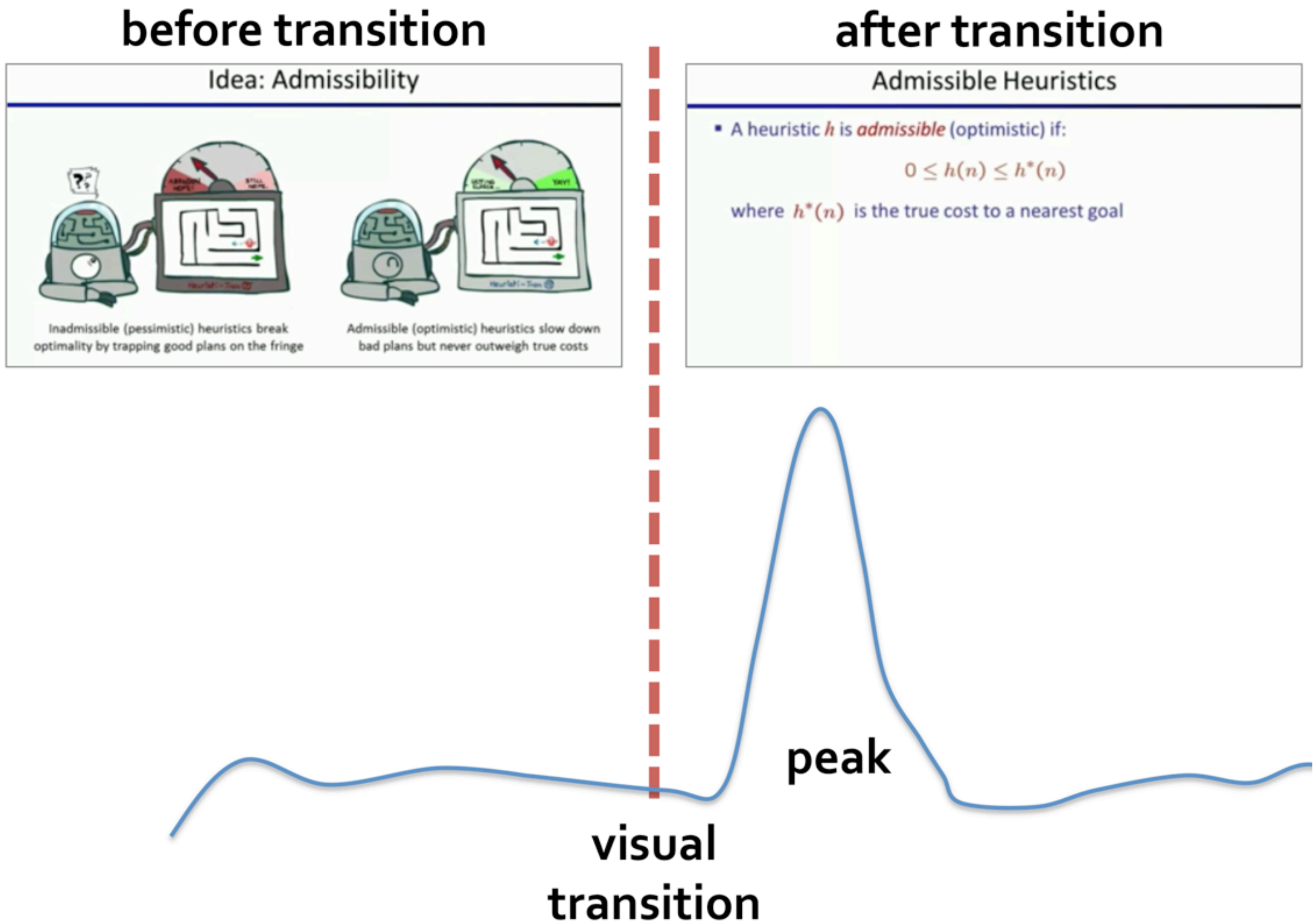
- We analyzed video interaction data from the lectures in 4 edX courses
  - Clickstream (play, pause, scrub)

Course	Subject	University	Students	Videos	Video Length	Processed Events
6.00x	Intro. CS & Programming	MIT	59,126	141	7:40	4,491,648
PH207x	Statistics for Public Health	Harvard	30,742	301	10:48	15,832,069
CS188.1x	Artificial Intelligence	Berkeley	22,690	149	4:45	14,174,203
3.091x	Solid State Chemistry	MIT	15,281	271	6:19	4,821,837
Total			**127,839**	**862**	**7:46**	**39,319,757**

Interaction Peaks

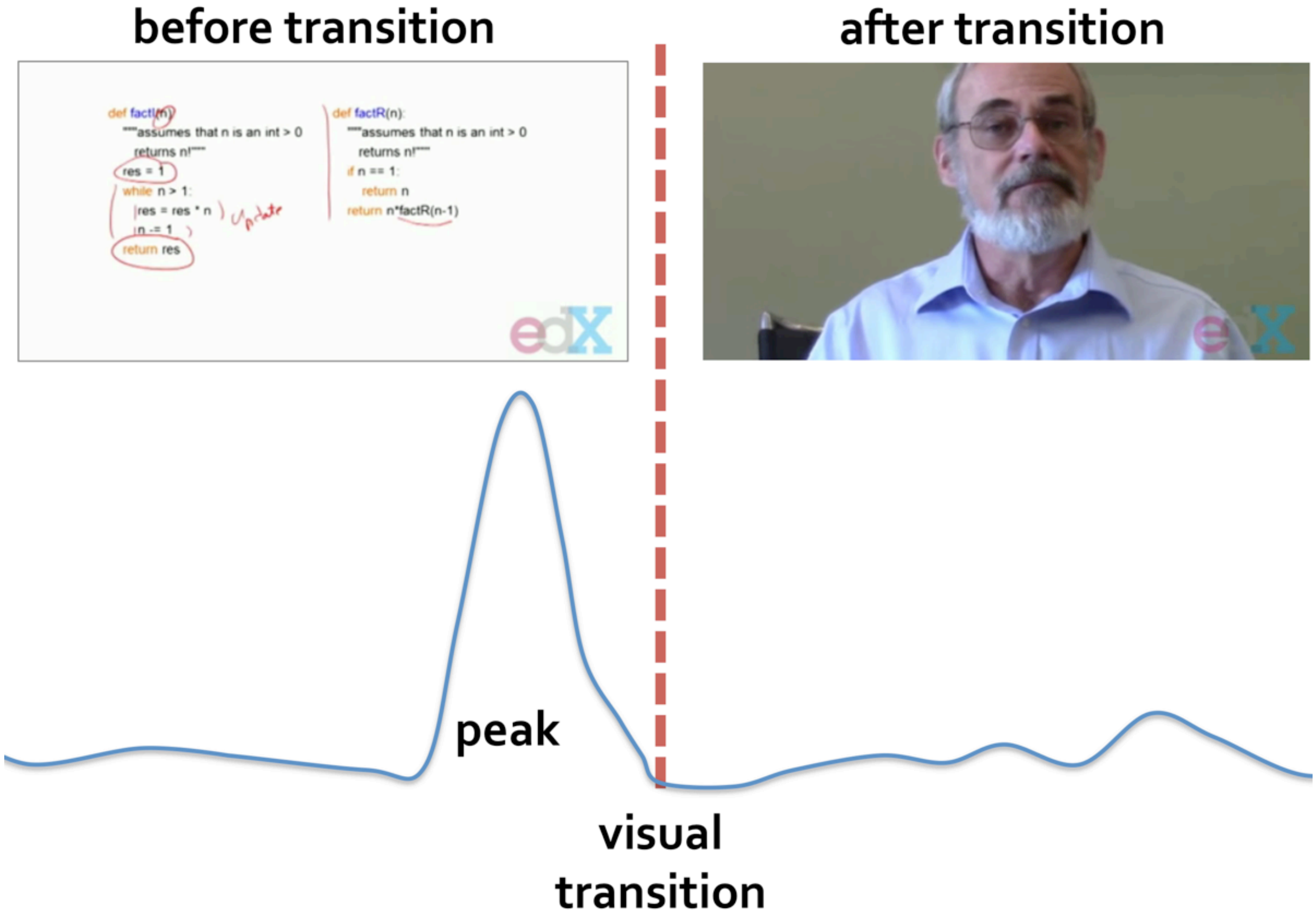


Example: Beginning of new material

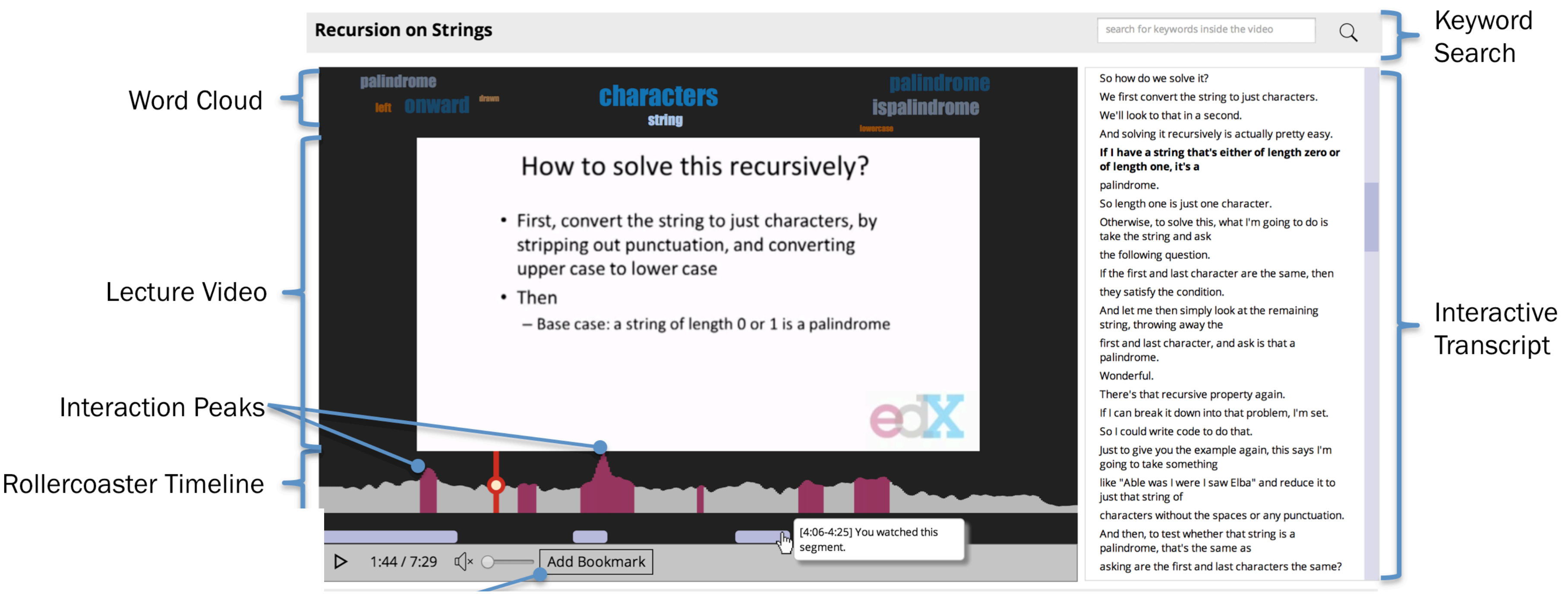


CSAIL

Example: Backing up



LectureScape: Enhancing lecture videos



SOLUTION ANALYTICS

Elena
Glassman

A Typical Programming Assignment

CSAIL

Time

Write an iterative function that computes a^b

What did our students do?

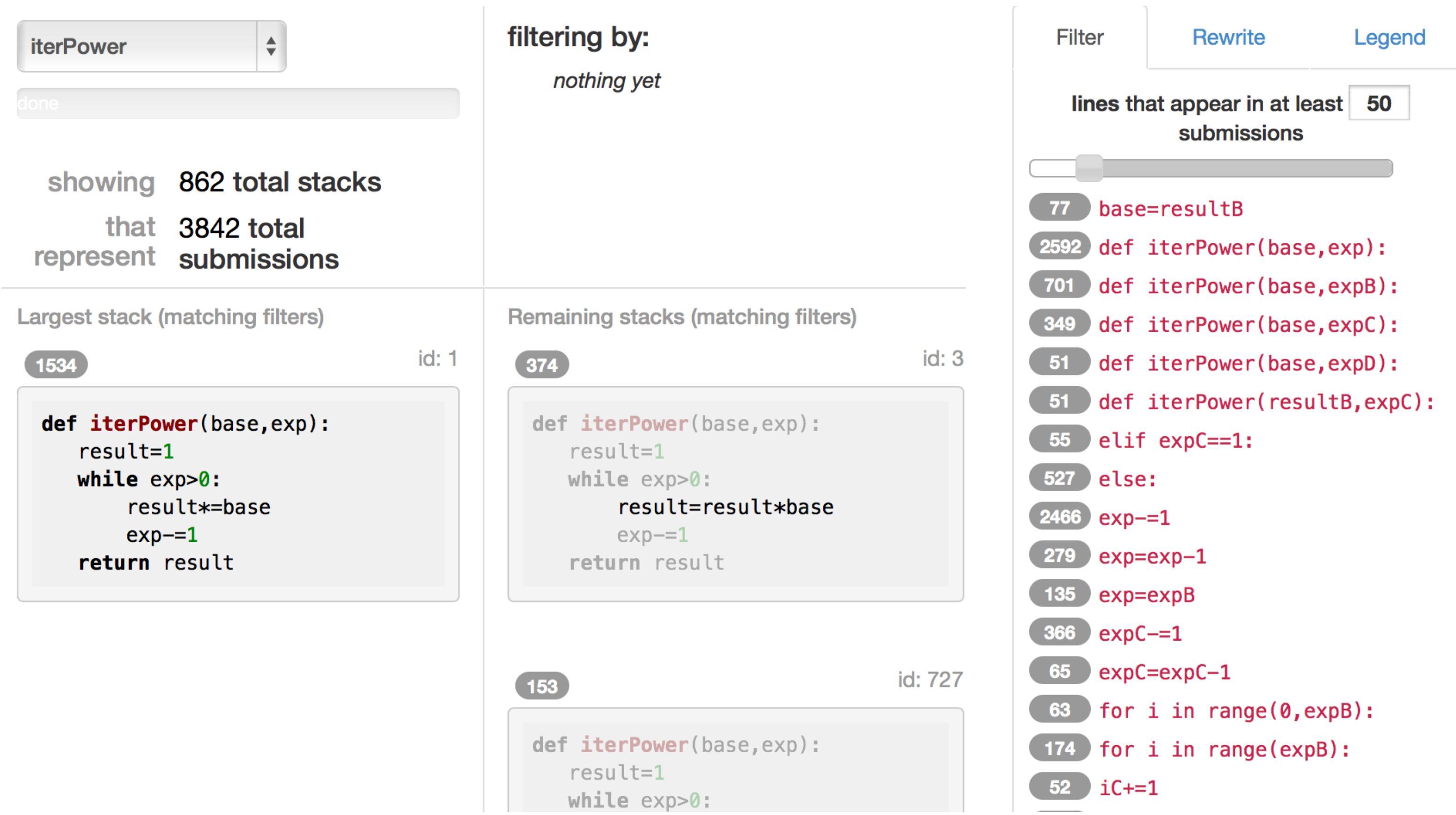
Oops, the autograder should have caught that.

Oh no! Never do that!

Clever--I didn't know you could do it that way.

OverCode

- Overcode allows teaching staff to see the similarity and variation among thousands of solutions.



Solution Cleaning & Clustering

CSAIL

- OverCode makes solutions easier to read and cluster
  - Reformat code for consistency
  - Rename variables with identical behavior
  - Ignore statement order when clustering solutions

```
def iterPower(base, exp):
    result = 1
    while(exp > 0):
        result *=base
        exp -=1
    re
```

```
def iterPower(base, exp):
    # Your code here
    res =1
    while exp> 0:
        exp-=1
        res *= base
    return res
```

```
def iterPower(base, exp):
    wynik=1
    while exp>0:
        wynik*=base
        exp-=1
    return wynik
```

```
def iterPower(base,exp):
    result=1
    while exp>0:
        result*=base
        exp-=1
    return result
```

	Total Solutions	Largest Stack		2nd Largest	
iterPower	~3800	1534	~40%	374	~10%
hangman	~1100	97	~9%	92	~9%
computeDeriv	~1400	22	~1%	13	~0.5%

iterPower — Largest Stack (1534):

```
def iterPower(base,exp):
    result=1
    while exp>0:
        result*=base
        exp-=1
    return result
```

iterPower — 2nd Largest (374):

```
def iterPower(base,exp):
    result=1
    while exp>0:
        result=result*base
        exp-=1
    return result
```

hangman — Largest Stack (97):

```
def getGuessedWord(secretWord,
    result=''
    for letter in secretWord:
        if letter in lettersGue
            result+=letter
        else:
            result+='_ '
    return result
```

hangman — 2nd Largest (92):

```
def getGuessedWord(secret
    resultB=''
    for letter in secretWo
        if letter in lette
            resultB+=lette
        else:
            resultB+='_'
    return resultB
```

computeDeriv — Largest Stack (22):

```
def computeDeriv(poly):
    result=[]
    if len(poly)==1:
        return[0.0]
    for i in range(1,len(poly))
        result.append(float(pol
    return result
```

computeDeriv — 2nd Largest (13):

```
def computeDeriv(poly):
    result=[]
    if len(poly)<2:
        return[0.0]
    for i in xrange(1,len(
        result.append(floa
    return result
```

Performance

OverCode preprocessing pipeline is **linear** with number of solutions and runs on a **laptop**

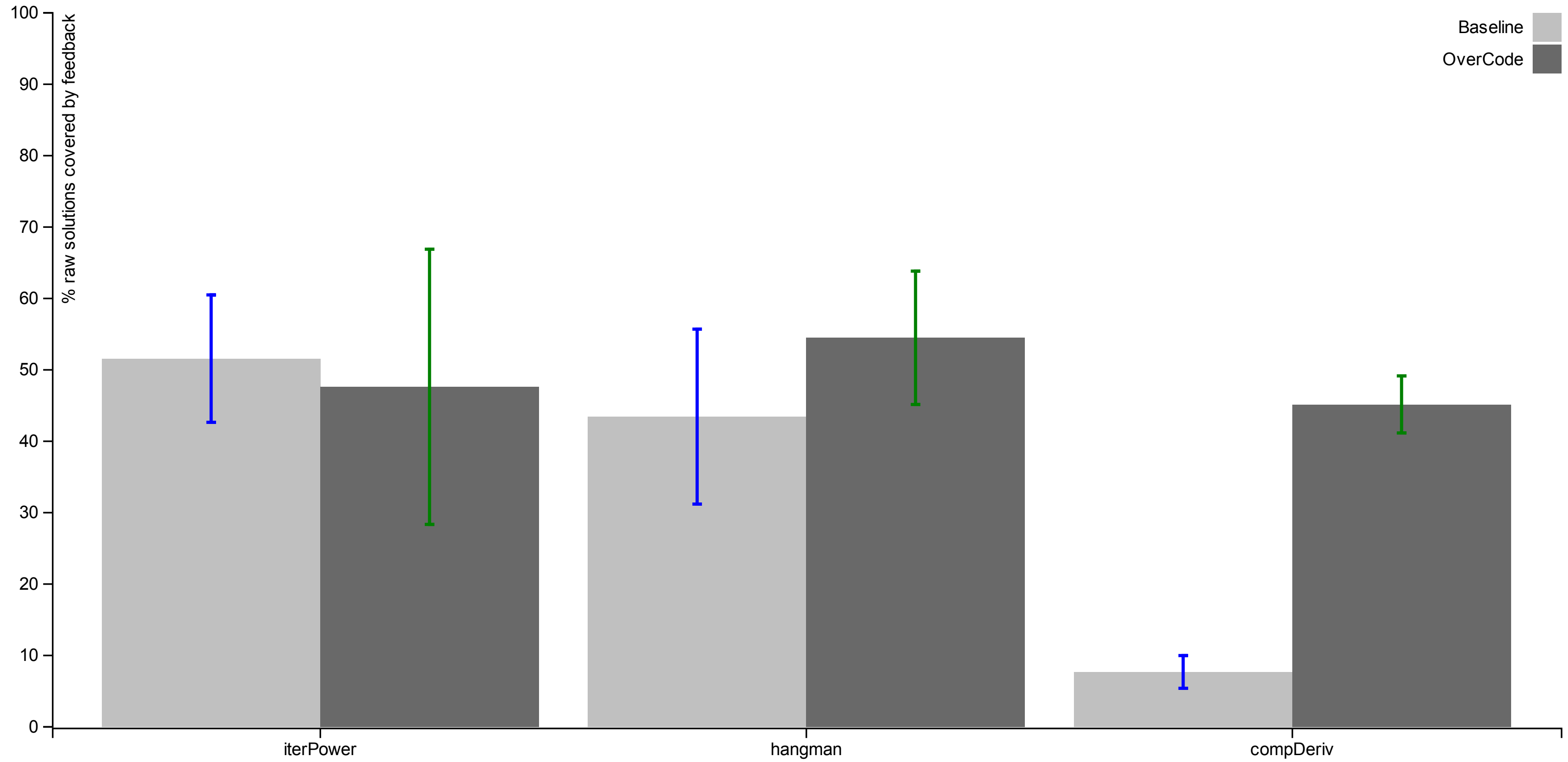
Problem	Correct Solutions	Running Time	Initial Stacks	Common Variables
`iterPower`	3875	15m 28s	862	38
`hangman`	1118	8m 6s	552	106
`compDeriv`	1433	10m 20s	1109	50

Other clustering approaches are quadratic in number of solutions and need a computer cluster.

Feedback Coverage

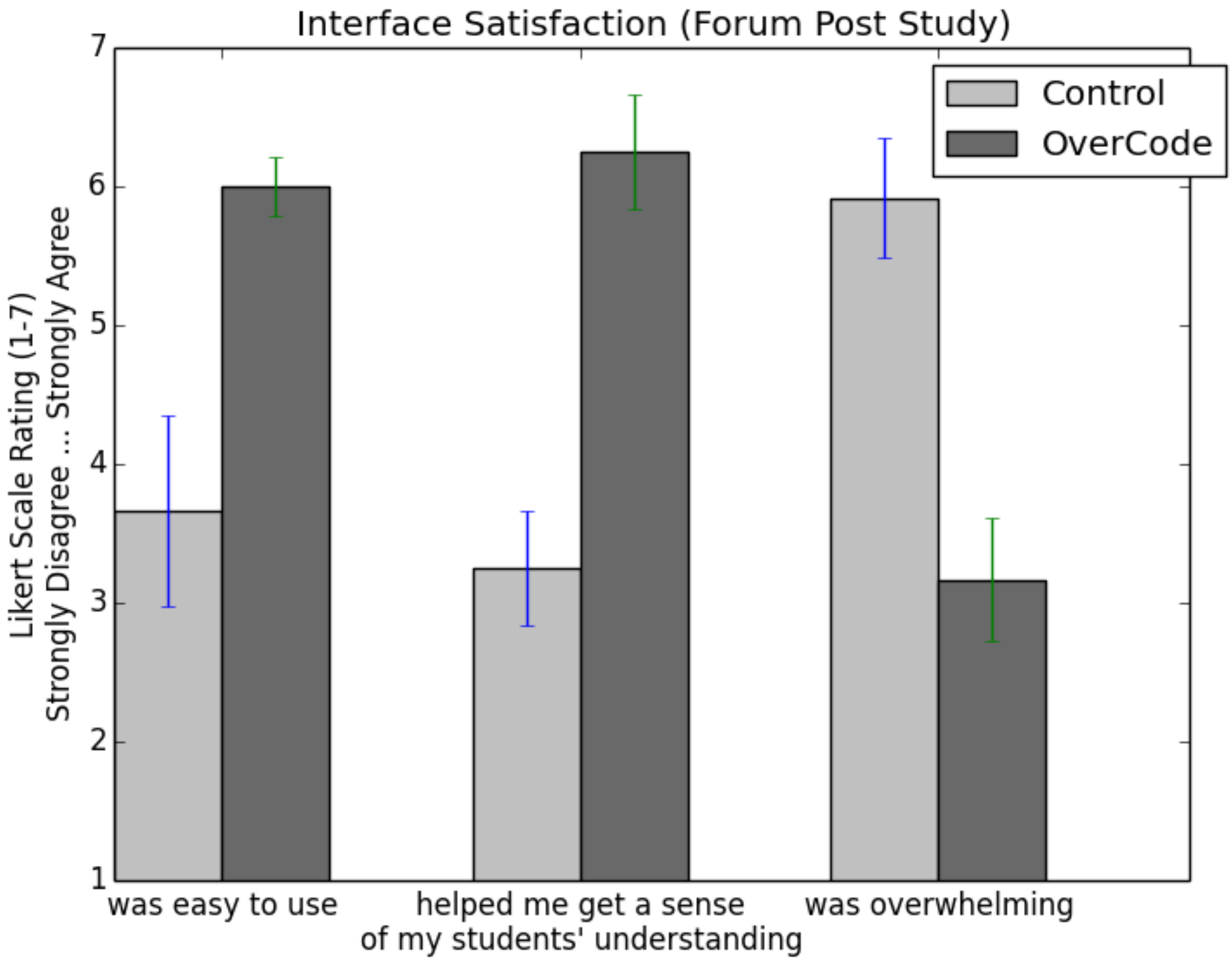
% solutions covered
by the teacher's post

users: 12 teaching assistants
control: all solutions concatenated in a page
task: write a discussion forum post



iterPower hangman computeDeriv

Teacher Perceptions



PEER CODE REVIEW

Problem: Feedback about Coding Style

- MIT 6.005 Software Construction
  - foundation-level programming course (replaced 6.001/6.170)
  - 400 students per year, mostly sophomores
- Students write lots of code
  - roughly 10kloc in problem sets and projects
- Automatic grading is necessary but not sufficient

```
// compute n!  requires n >= 0
int factorial(int n) {
    if (n == 0) return 1;
    else return n * factorial(n-1);
}
```

correct and understandable

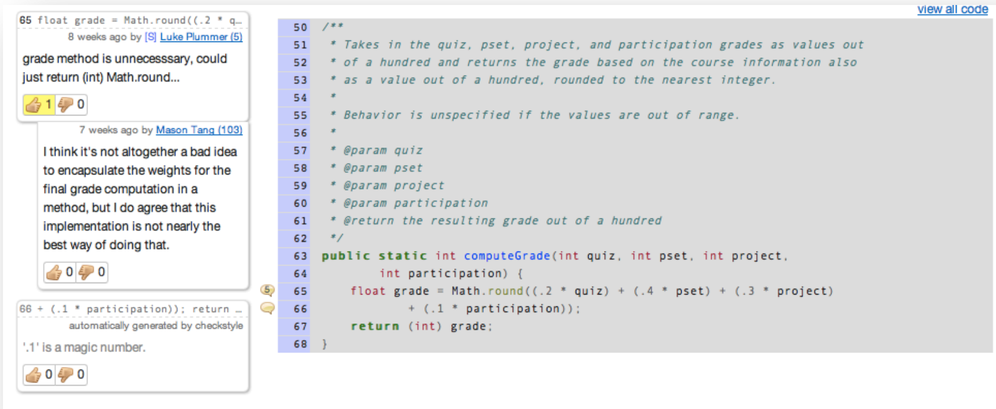
```
int factorial(int n) {
    int i, result=1;
    if (n == 0) result = 1;
    else {
        for (i = 1; i < n; ++i) result *= i;
        result = result*n;
        return result;
    }
    return 1;
}
```

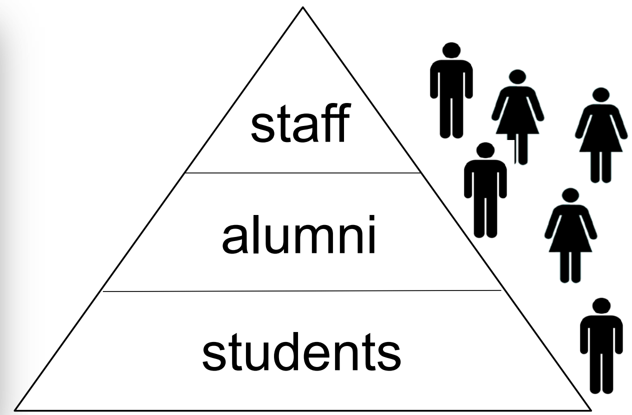
correct but confusing

  - we need human readers, and we want line-by-line feedback

Approach: Crowd-Driven Code Review

- Chop up student programs into **chunks**
- Review the chunks by a **mixed crowd**: students, staff, alums





- Anticipated benefits
  - faster, cheaper, more diverse comments
  - give practice with code reviewing (a widespread industry practice)
  - expose to good and bad solutions
  - reduce workload on teaching staff
  - incorporate alumni back into the course
- Not using for grading... yet

Caesar: Divide & Conquer

```
public class RulesOf6005 {


    /**
     * Tests if the string is one of the items in the Course Elements section.
     *
     * @param name - the element to be tested
     * @return true if <name> appears in bold in Course Elements section. Ignores case (capitalization).
     * Example: "Lectures" and "lectures" will both return true.
     */
    public static boolean hasFeature(String name){
        // TODO: Fill in this method, then remove the RuntimeException
        String[] elements = { "lectures", "recitations", "laptops required", "text", "problem sets", "
        String test = name.toLowerCase();
        for (int ii = 0; ii < 9; ii++) {
            if (elements[ii].equals(test)) {
                return true;
            }
        }
        return false;
    }


    /**
     * Takes in the quiz, pset, project, and participation grades as values out of a
     * hundred and returns the grade based on the course information also as a value out
     * of a hundred, rounded to the nearest integer.
     *
     * Behavior is unspecified if the values are out of range.
     *
     * @param quiz
     * @param pset
     * @param project
     * @param participation
     * @return the resulting grade out of a hundred
     */
    public static int computeGrade(int quiz, int pset, int project, int participation){
        return (int)Math.round((quiz*.2) + (pset*.4) + (project*.3) + (participation*.1));
    }


    /**
     * Based on the slack day policy, returns a date of when the assignment would be due, making sure not
     * exceed the budget. In the case of the request being more than what's allowed, the latest possible
     * due date is returned.
     *
     * Hint: Take a look at http://download.oracle.com/javase/6/docs/api/java/util/GregorianCalendar.html
     *
     * Behavior is unspecified if request is negative or duedate is null.
```

programs chopped into **chunks**

each chunk assigned to multiple reviewers

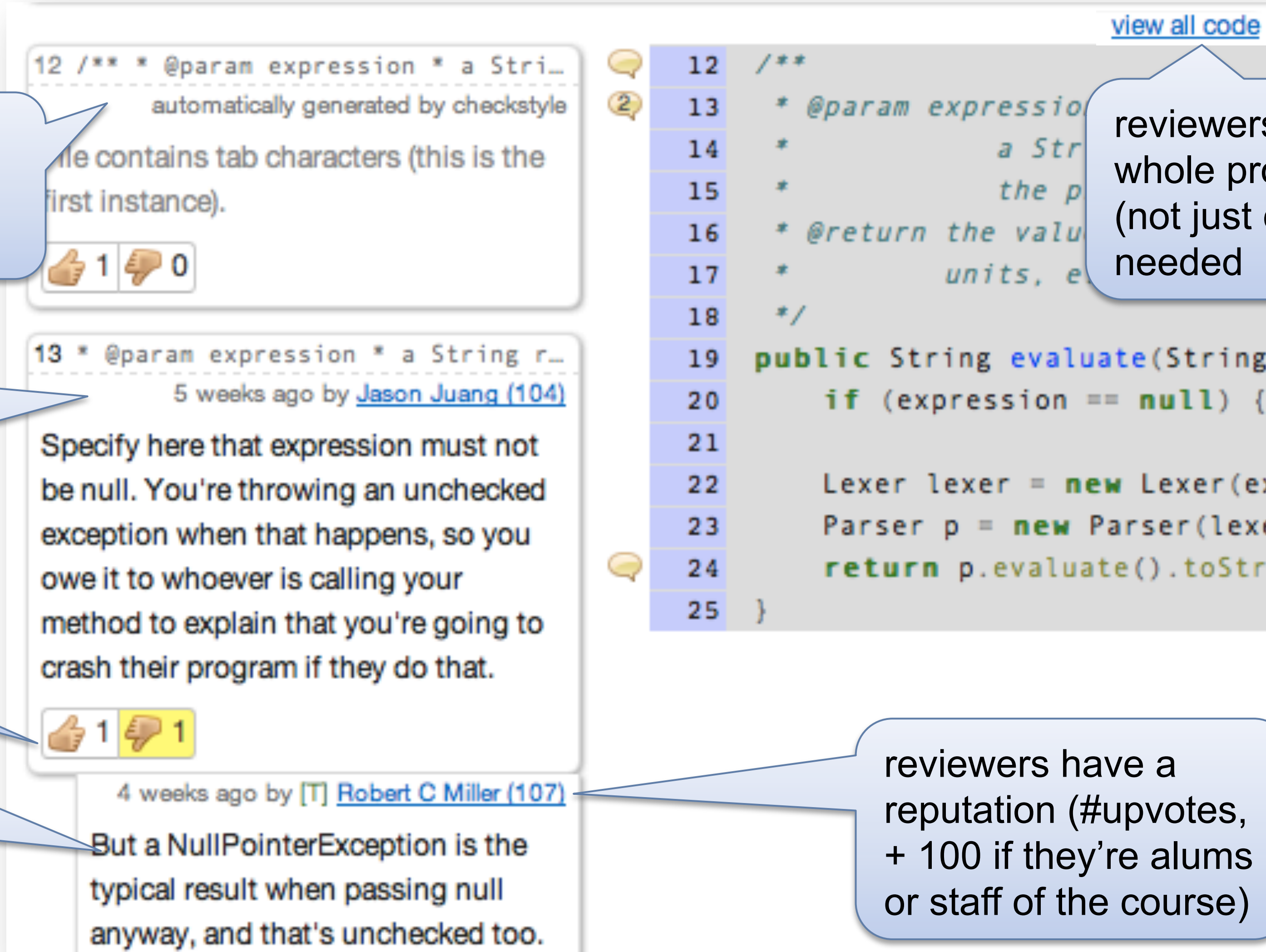
code to review

PrimeFactorsServer	5	1
PrimeFactorsServer	5	1
EchoClient	1	1
EchoClient	5	1
EchoClient	3	1
EchoServer	3	1
PrimeFactorsClient	6	1
PrimeFactorsServer	6	1
EchoClient	2	1
EchoClient	2	1

code recently reviewed

RulesOf6005.extendDeadline(..)	18	2
RulesOf6005.extendDeadline(..)	4	3
RulesOf6005.computeGrade(..)	9	3
RulesOf6005.extendDeadline(..)	6	2
RulesOf6005.computeGrade(..)	6	3
RulesOf6005.hasFeature(..)	3	2
RulesOf6005.hasFeature(..)	6	2
RulesOf6005.hasFeature(..)	4	2
RulesOf6005.hasFeature(..)	5	2
RulesOf6005.hasFeature(..)	4	2

Social Reviewing



automatic style checker comments

reviewer comments

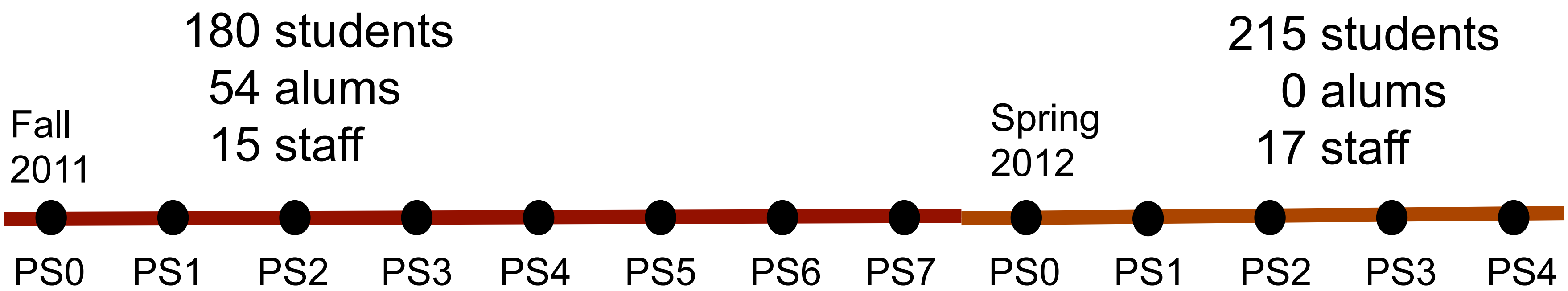
upvotes & downvotes

replies & discussion

reviewers can see whole program (not just chunk) if needed

reviewers have a reputation (#upvotes, + 100 if they're alums or staff of the course)

Experience

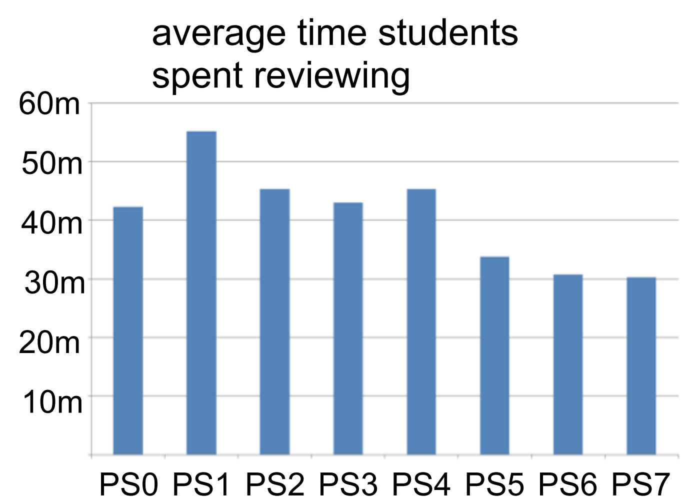


13 problem sets, 2200 submissions

21,500 comments
5% alums
8% staff
87% students

16.2% upvoted
0.7% downvoted

9.6 comments per submission



Kinds of Comments

- Bug
- Clarity
- Performance
- Simplicity
- Style
- Positive
- Learning

- I don't really understand what you're

- This is nice and concise. (I didn't know you could iterate through an array like this in a for loop)

- This is interesting. Why do you store all the messages you send/ receive in a log?

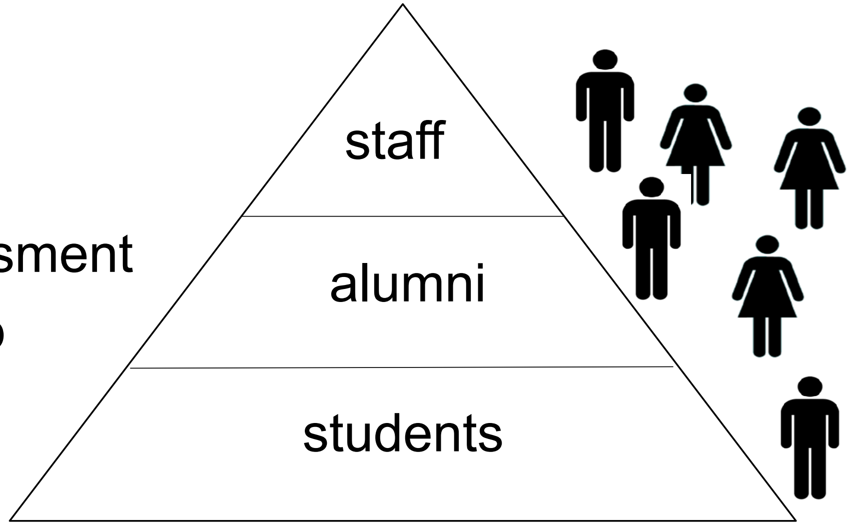
  Code author: For debugging. The log adds time stamps, which help a lot for debugging concurrency problems.

A LOOK AHEAD

MOOCs Have to Run Themselves

CSAIL

- Launching a MOOC is like authoring a textbook
  - But keeping it running currently requires sustained expert involvement
  - In the long run, we can teach the world for free only if we don't have to staff the MOOCs
- Implications
  - Intelligent tutor systems
  - Peer help, feedback, assessment
  - Alumni or external staff help



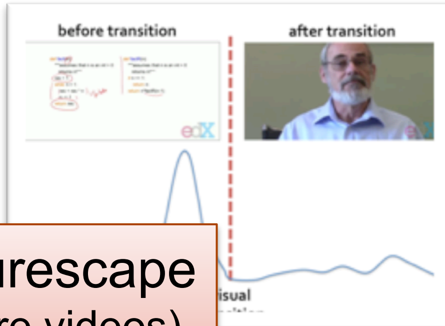
MOOCs Have to Improve Themselves

- edX and Coursera will be littered with stale MOOCs
  - Because faculty have no time or incentive to revise them
  - In the long run, MOOCs have to revise and improve themselves, automatically
- Implications
  - Crowdsourced content: exercises, quizzes, textbook, videos
  - FrankenMOOCs that combine the best stuff out there
  - Video content that can be edited like Wikipedia

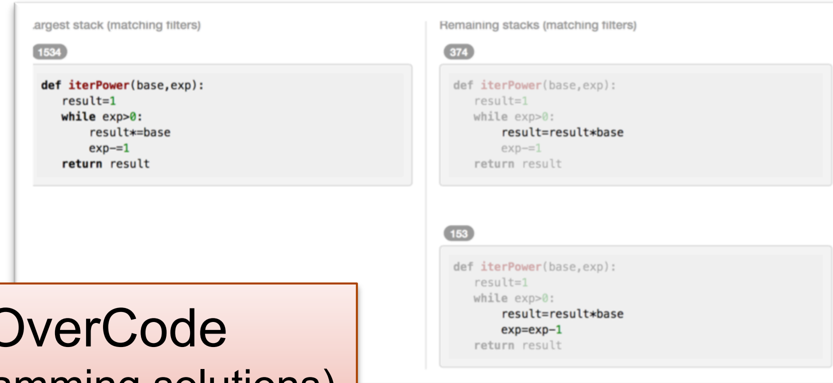
MOOCs Are Big Data for Education

- Google and Bing drive information retrieval research
  - because they own the data & control the interface
- Facebook and Twitter increasingly drive social network research
  - again: data + interface
- Universities could be driving learning science in CS
  - if we step up and take ownership of the data + the interface

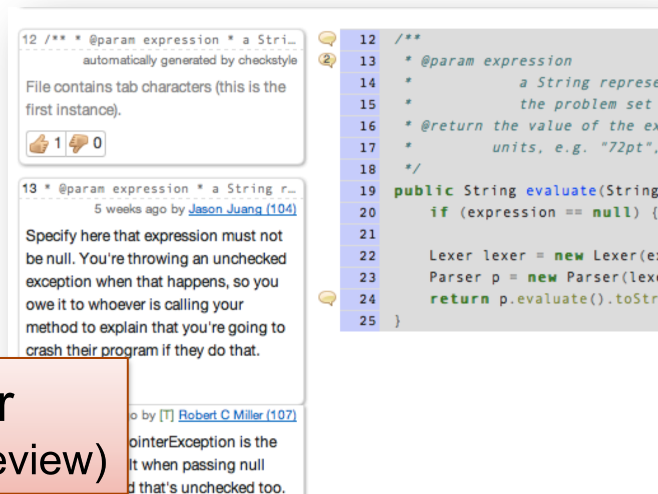
Summary



Lecturescape
(lecture videos)



OverCode
(programming solutions)



Caesar
(peer code review)

future
- self-running MOOCs
- self-improving MOOCs
- MOOCs are our big data

Thanks to support from NSF, Quanta Computer, Google, edX

MIT HUMAN-COMPUTER INTERACTION