ASSISTments + Web pages = WEBsistments

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Caution!

- First time presenting this work
- Will appear at ITS
- (Very, very extensible)

Big points

- Educational content litters the web
  - Is a game-changer for ITS
  - Extend capabilities of ITS
  - Very low cost for ITS designers

- Produce an interesting research program

In the beginning…

- There was the LISP tutor (1984)
  - And it was without instruction…
- Environment designed for *coached problem solving*
- Assumption is that students learned *declarative knowledge* elsewhere (from the course textbook)

Others followed in their footsteps

- Emphasis of ITS has generally been on coached problem solving
  - Usually procedural skills
- Assumption is students have learned background for material in the class
  - → little teaching within ITS

2x

Break this problem into steps

Type your answer below (mathematical expression):

23

Submit Answer | Show me a web page

b. Perimeter
c. Equation-Solving

✗ Sorry, that is incorrect. Let's move on and figure out why!

Which side of triangle ABC has the same length as side DF of triangle DEF?

Show me hint 1 of 3

Select one:

- AB
- BC
- AC

Submit Answer

The 1st scaffolding question

Congruence

✓ Correct!

Which expression represents the perimeter of triangle ABC?

Perimeter is defined as the sum of all sides of a figure.

The 1st hint message

The perimeter of triangle ABC is the sum of all its sides.

The 2nd hint message

Show me the last hint

Select one:

- 2x + 8
- 2x + x + 8
- $^1/_2$ * 8x
- $^1/_2$ * x(2x)

A buggy message in response to an **incorrect answer**

The 2nd scaffolding question

Perimeter

Submit Answer

Why this separation? 3 reasons

- **Focus on what technology is good at**
  - We have a reasonable mechanism for transmitting declarative knowledge to students (textbooks and lectures)
  - We lacked a means for students to practice those skills and get feedback

- → procedural ITS

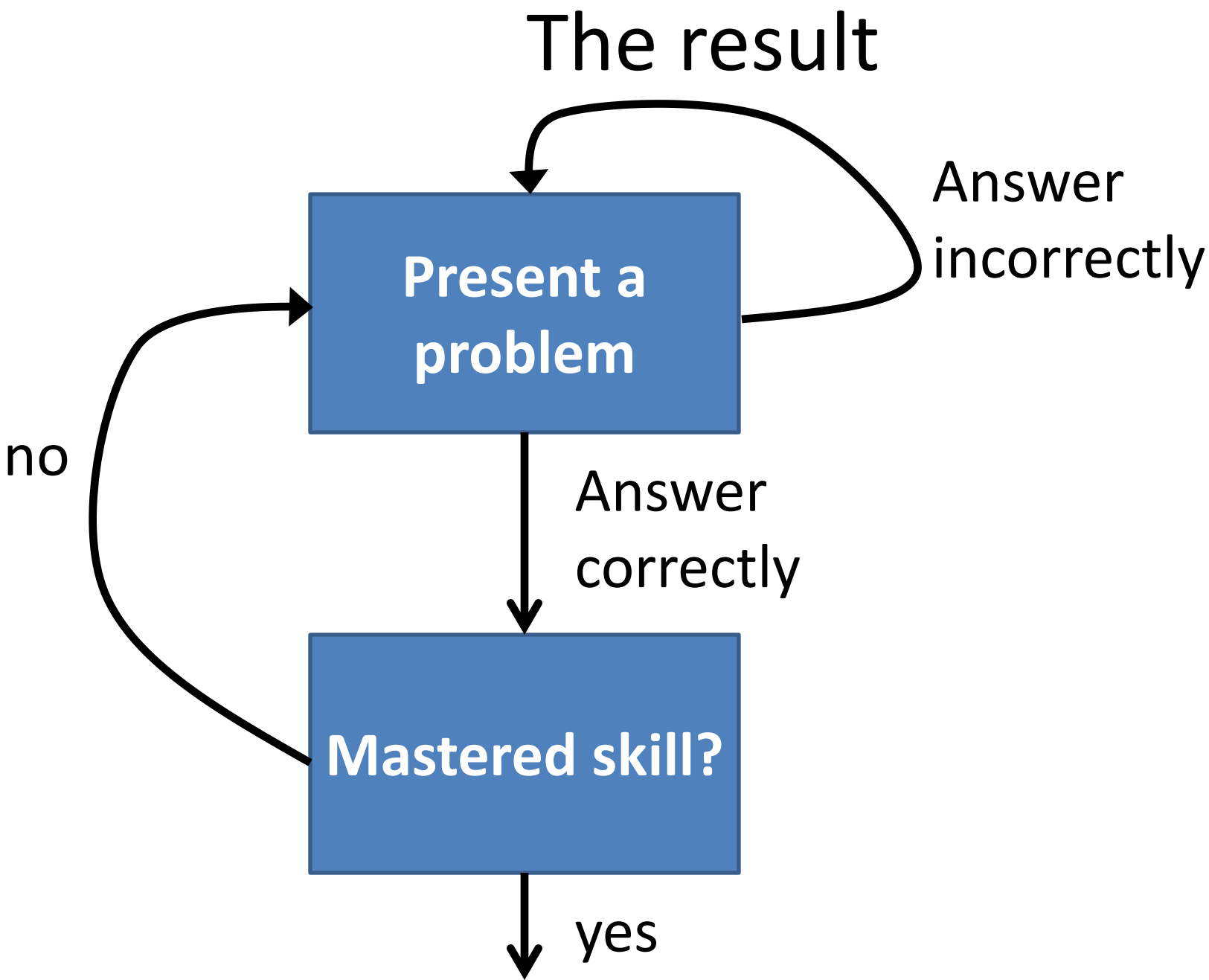
#2 Cost of adding teaching

- ITS are expensive artifacts to create (estimate is 100 hours for each hour of instruction)
  - Possibly optimistic

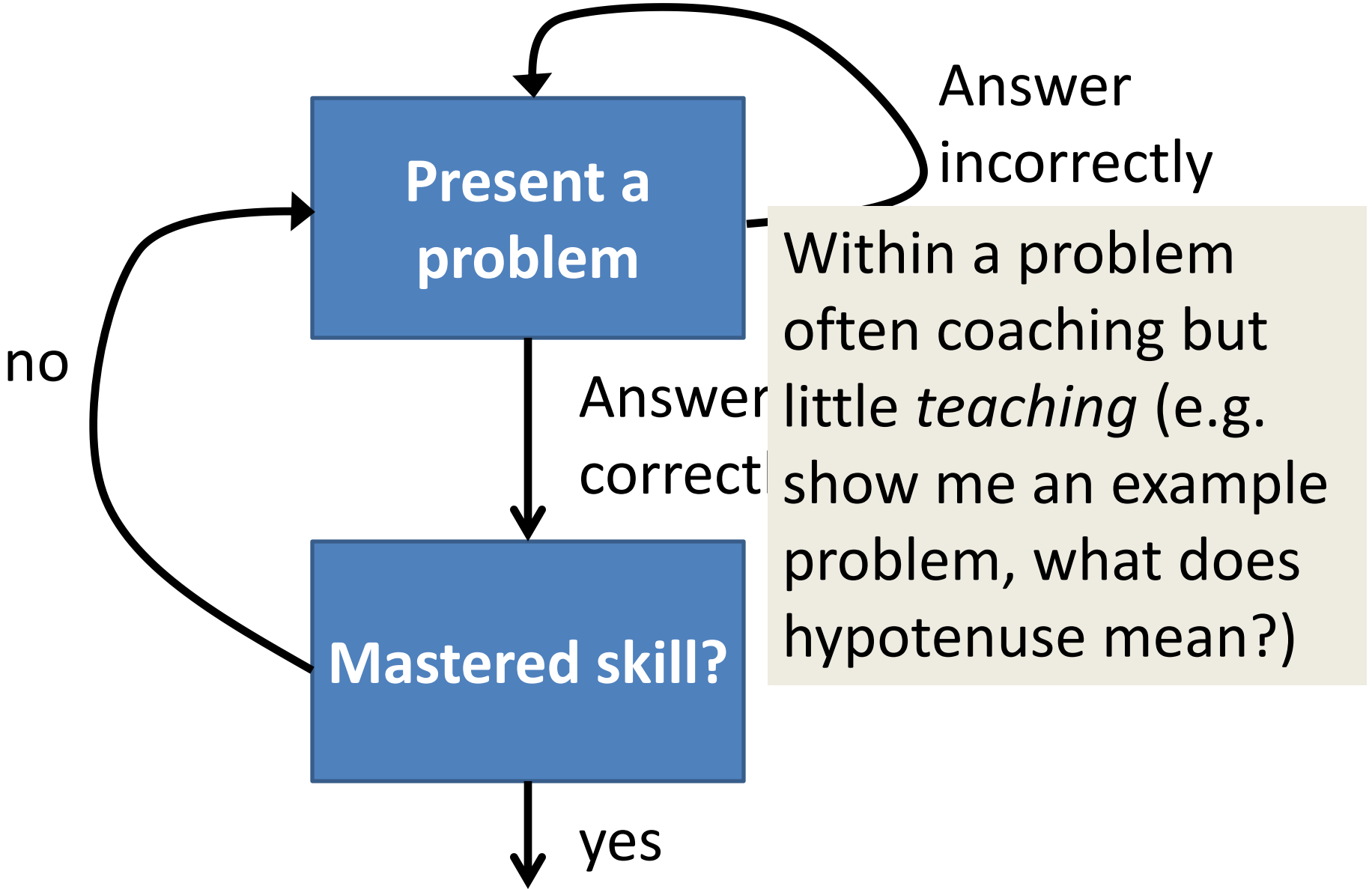
- Costs would be even higher if added teaching capabilities to an ITS

#3 Skill set of developers

- Designing and developing an ITS requires:
  - Knowledge representation, cognitive model, programming, user interface
- Teaching requires:
  - Conceptual understanding, domain knowledge, communication skills
- Some overlap, but rather different set of skills
  - → even more people on the project
    - → more $$$ and higher communication costs


The result
Present a problem
Answer incorrectly
no
Answer correctly
Mastered skill?
yes

The result



Within a problem often coaching but little *teaching* (e.g. show me an example problem, what does hypotenuse mean?)

So what's wrong?

- There is much more to education than procedural problem solving
  - We all agree with that
  - But why don't most ITS handle it?

So what's wrong?

- There is much more to education than procedural problem solving
  - We all agree with that
  - But why don't most ITS handle it?

- One definition of an academic discipline: a group of people who all agree not to ask certain awkward questions
  - "Where's the teaching!?"

Goal

- Keep practiced problem solving component
  - We're good at that, let's not lose it!
  - But also allow ITS to teach
- Must be accomplished cheaply
- Should scale well as ITS grows
  - i.e. cannot create instruction for every problem in the system

Possible solutions

- Create content
  - Too expensive
- *Find* content
  - There's a whole web of content out there
  - If only there was some way to search it…
  - (demo)

Shift in emphasis: 3 steps

- Rather than creating content, our goal is to find *good* content
  - Lots of web pages, need to filter them somehow
- Link content to the ITS
- Decide when to present the instruction

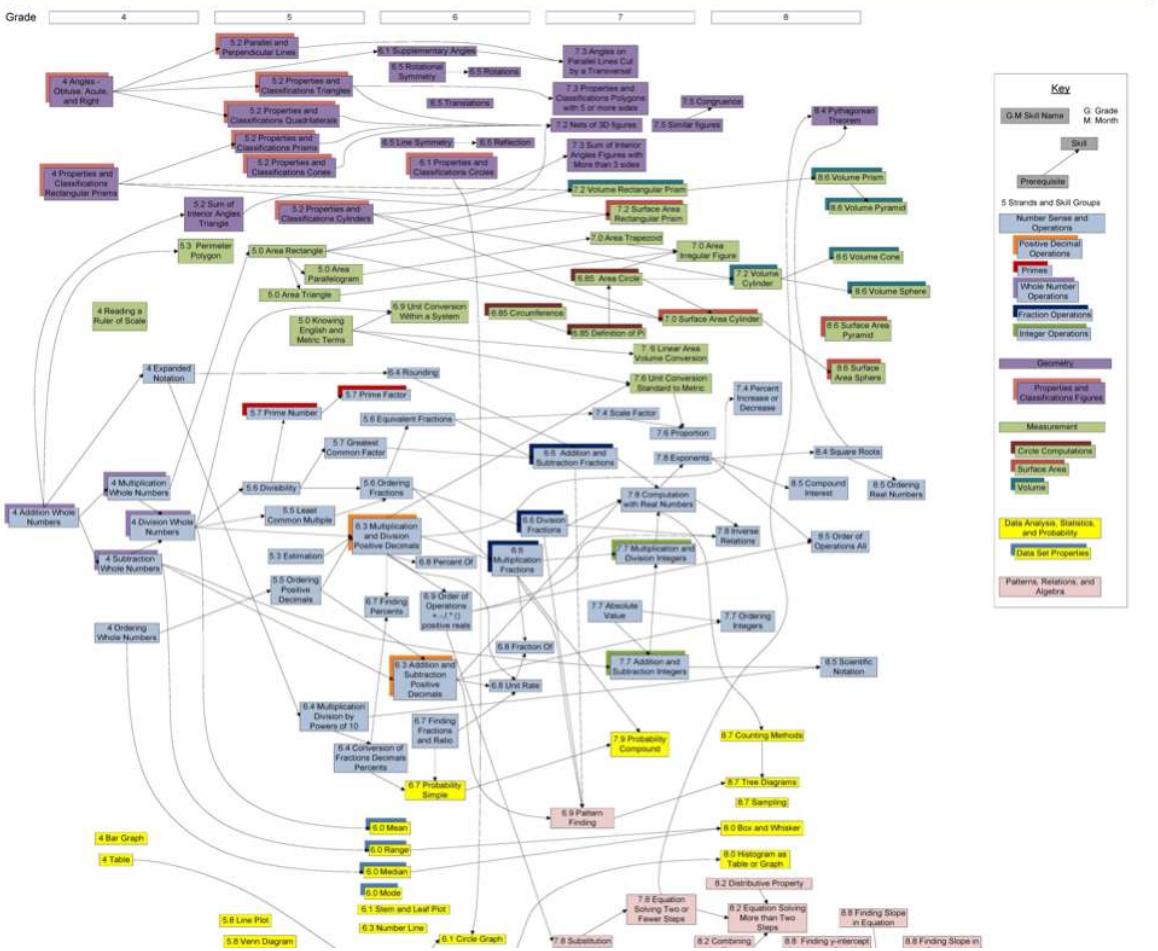
#1: How to find good content?

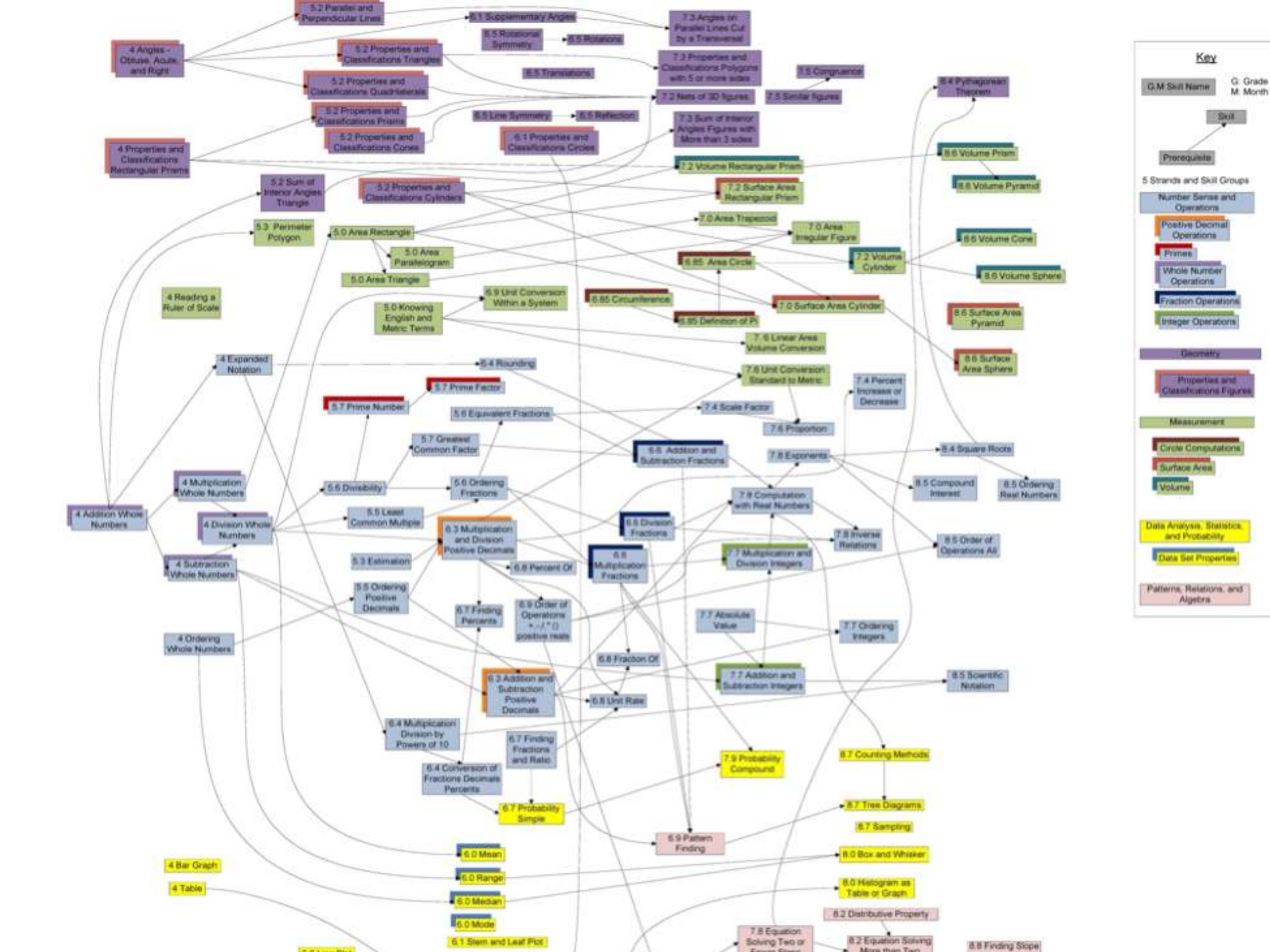
- Start with (under)graduate students using google
  - Students and subject-matter expert inspect candidate pages and reject some as inappropriate
  - Much faster to rate than to create
- Teachers also suggest pages
  - We start by only presenting it to students in that teacher's class (sanity check)
  - Promising pages are migrated to main list of web pages

#2: How to link to ITS?

- ASSISTments has skill map of 150 skills and prerequisite relationship

ASSISTments skill map




4 Angles - Obtuse, Acute, and Right
5.2 Parallel and Perpendicular Lines
6.1 Supplementary Angles
7.3 Angles on Parallel Lines Cut by a Transversal
6.5 Rotational Symmetry
6.5 Rotations
5.2 Properties and Classifications Triangles
7.3 Properties and Classifications Polygons with 5 or more sides
6.5 Translations
7.5 Congruence
5.2 Properties and Classifications Quadrilaterals
7.2 Nets of 3D figures
7.5 Similar figures
8.4 Pythagorean Theorem
5.2 Properties and Classifications Prisms
6.5 Line Symmetry
6.5 Reflection
7.3 Sum of Interior Angles Figures with More than 3 sides
5.2 Properties and Classifications Cones
6.1 Properties and Classifications Circles
4 Properties and Classifications Rectangular Prisms
7.2 Volume Rectangular Prism
8.6 Volume Prism
8.6 Volume Pyramid
5.2 Sum of Interior Angles Triangle
5.2 Properties and Classifications Cylinders
7.2 Surface Area Rectangular Prism
5.3 Perimeter Polygon
5.0 Area Rectangle
7.0 Area Trapezoid
7.0 Area Irregular Figure
8.6 Volume Cone
5.0 Area Parallelogram
6.85 Area Circle
7.2 Volume Cylinder
8.6 Volume Sphere
5.0 Area Triangle
4 Reading a Ruler or Scale
6.9 Unit Conversion Within a System
6.85 Circumference
7.0 Surface Area Cylinder
8.6 Surface Area Pyramid
5.0 Knowing English and Metric Terms
6.85 Definition of Pi
7.6 Linear Area Volume Conversion
8.6 Surface Area Sphere
4 Expanded Notation
6.4 Rounding
7.6 Unit Conversion Standard to Metric
7.4 Percent Increase or Decrease
5.7 Prime Factor
5.7 Prime Number
5.6 Equivalent Fractions
7.4 Scale Factor
7.6 Proportion
5.7 Greatest Common Factor
6.5 Addition and Subtraction Fractions
7.8 Exponents
8.4 Square Roots
4 Multiplication Whole Numbers
5.5 Divisibility
5.6 Ordering Fractions
7.8 Computation with Real Numbers
8.5 Compound Interest
8.5 Ordering Real Numbers
4 Addition Whole Numbers
4 Division Whole Numbers
5.6 Least Common Multiple
6.6 Division Fractions
7.8 Inverse Relations
6.3 Multiplication and Division Positive Decimals
6.8 Multiplication Fractions
7.7 Multiplication and Division Integers
8.5 Order of Operations All
5.3 Estimation
6.8 Percent Of
4 Subtraction Whole Numbers
5.5 Ordering Positive Decimals
6.7 Finding Percents
6.9 Order of Operations + - / * () positive reals
7.7 Absolute Value
7.7 Ordering Integers
4 Ordering Whole Numbers
6.8 Fraction Of
6.3 Addition and Subtraction Positive Decimals
7.7 Addition and Subtraction Integers
8.5 Scientific Notation
6.8 Unit Rate
6.4 Multiplication Division by Powers of 10
6.7 Finding Fractions and Ratio
6.4 Conversion of Fractions Decimals Percents
8.7 Counting Methods
7.9 Probability Compound
6.7 Probability Simple
8.7 Tree Diagrams
8.7 Sampling
6.9 Pattern Finding
4 Bar Graph
6.0 Mean
8.0 Box and Whisker
4 Table
6.0 Range
8.0 Histogram as Table or Graph
6.0 Median
8.2 Distributive Property
6.0 Mode
6.1 Stem and Leaf Plot
7.8 Equation Solving Two or
8.2 Equation Solving
8.8 Finding Slope
Key
G.M Skill Name
G: Grade
M: Month
Skill
Prerequisite
5 Strands and Skill Groups
Number Sense and Operations
Positive Decimal Operations
Primes
Whole Number Operations
Fraction Operations
Integer Operations
Geometry
Properties and Classifications Figures
Measurement
Circle Computations
Surface Area
Volume
Data Analysis, Statistics, and Probability
Data Set Properties
Patterns, Relations, and Algebra

#2: How to link to ITS?

- ASSISTments has skill map of 150 skills and prerequisite relationship

- Each skill is tagged with associated web pages

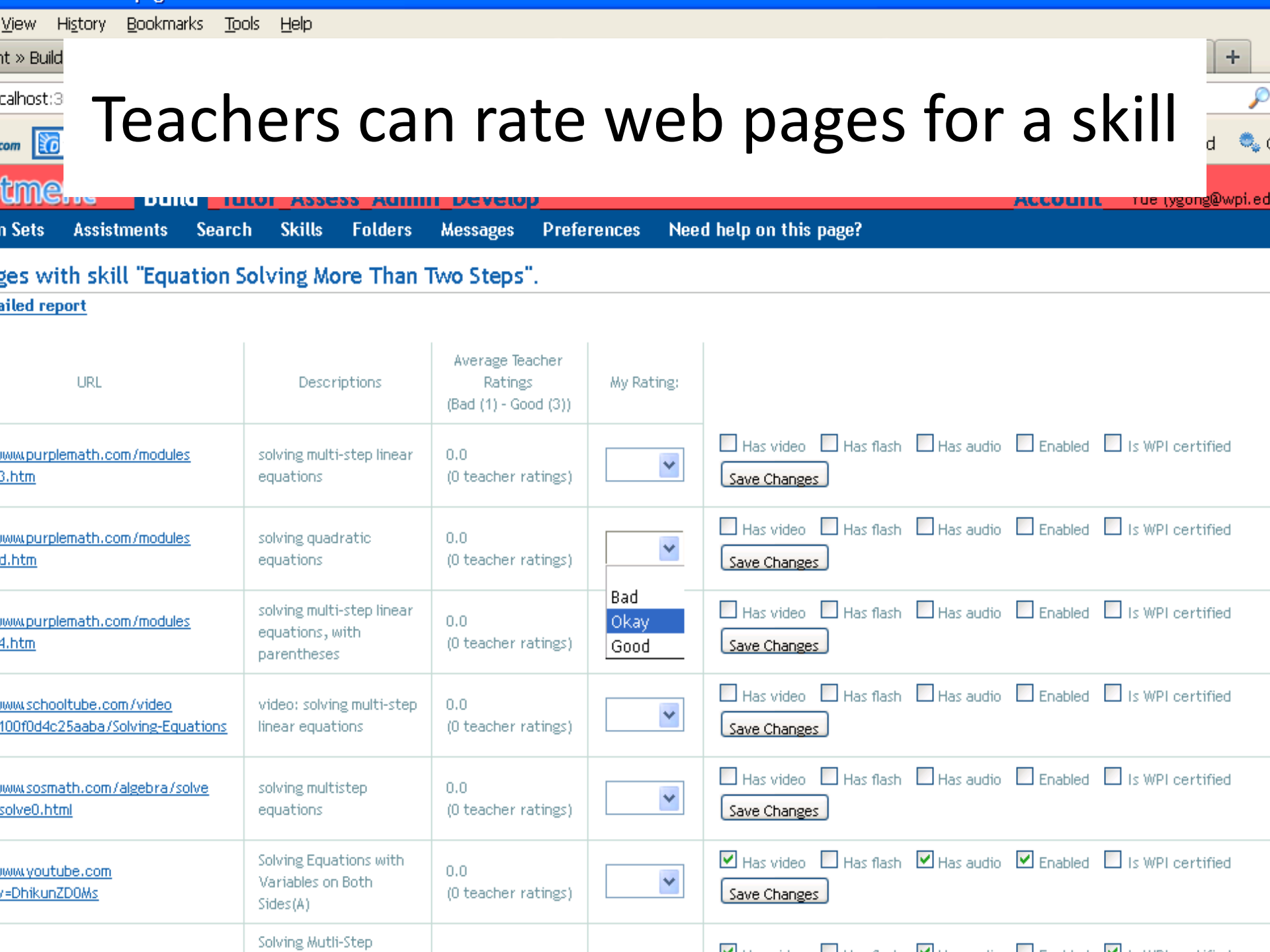
Build › Skills

This page offers the mappings between the 'WPI Math Fine Grained Model' and other known math skill sets/standards. WPI's fine grained model is break down and organization of the various topics to be covered throughout a student's education. For your convenience, we have mapped our down to other well known skill sets/standards.

Skill Sets: WPI Math Fine Grained Model to Common Core / WPI

WPI Math Fine Grained Model	WPI Math Fine Grained Model to Common Core
Box and Whisker (info) webpages	6.SP.4 (info)
Table (info) webpages	6.SP4 (info)
Point Plotting (info) webpages	6.NS.6 (info)
Graph Shape (info) webpages	8.F.5 (info)
Venn Diagram (info) webpages	
Mean (info) webpages	6.SP.5 (info)
Median (info) webpages	6.SP.5 (info)
Mode (info) webpages	6.SP.5 (info)
Range (info) webpages	6.SP.5 (info)
Counting Methods (info) webpages	7.SP.8 (info)
Probability of Two Distinct Events (info) webpages	
Probability of a Single Event (info) webpages	

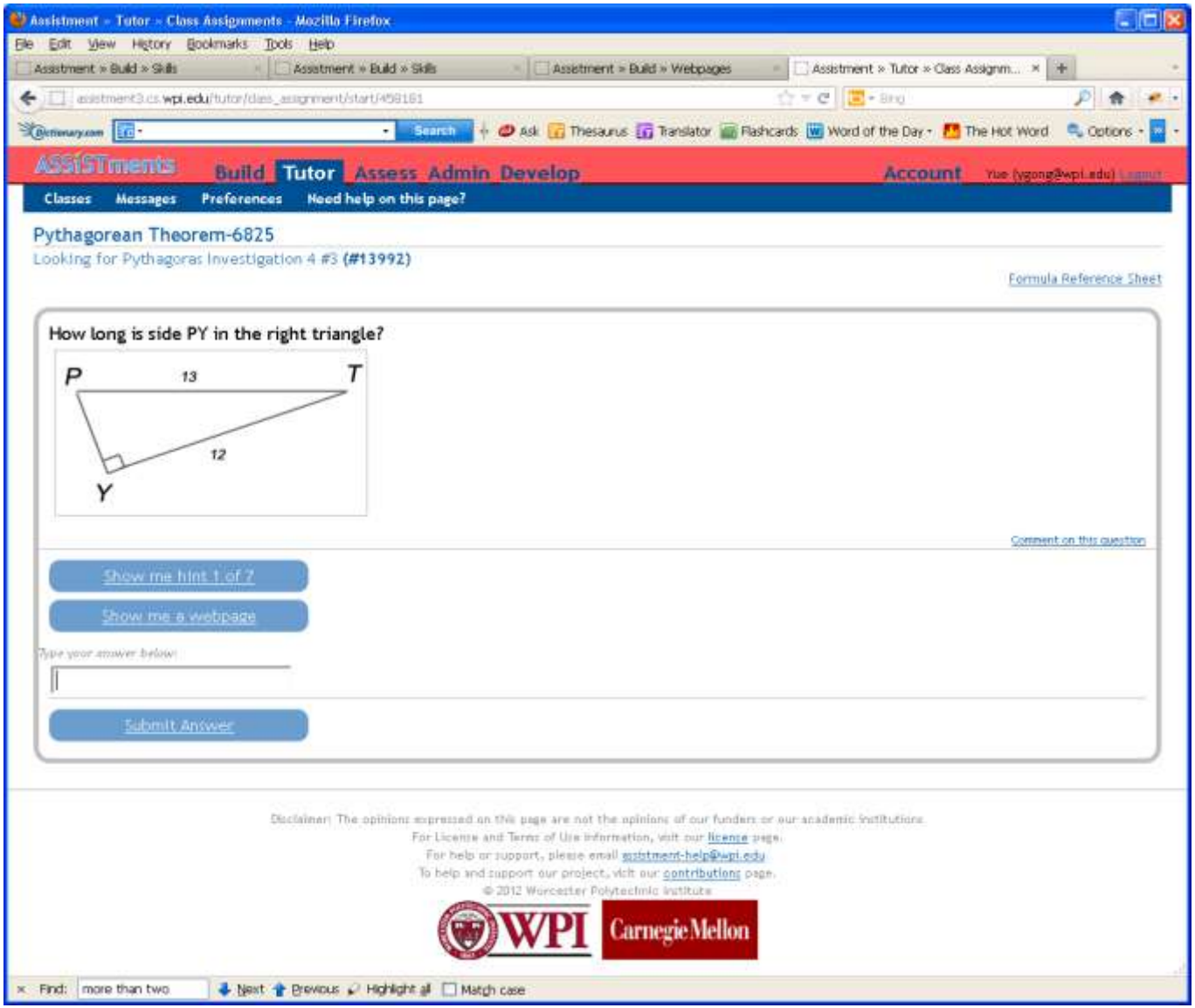
Teachers can rate web pages for a skill



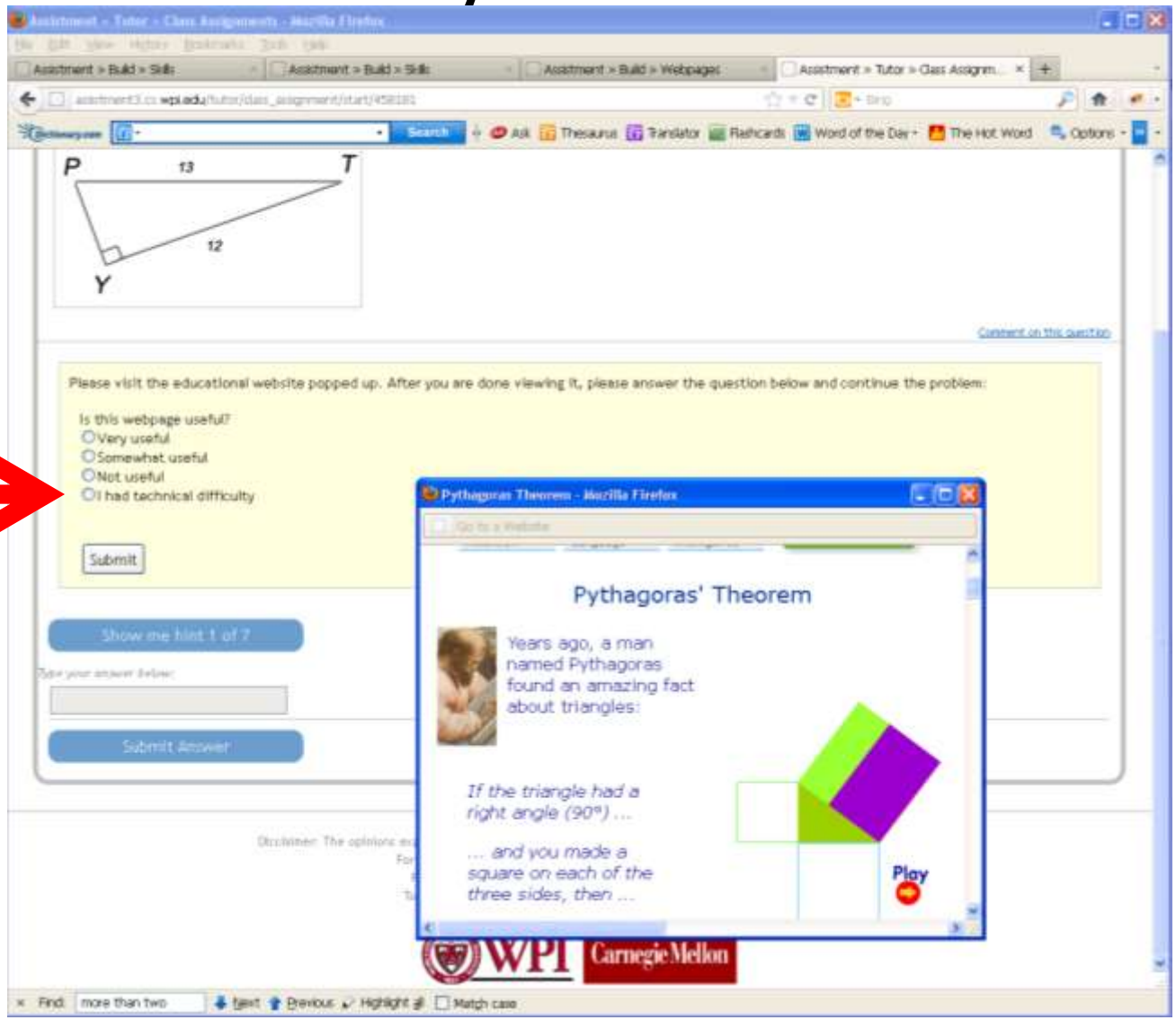
#3: When to present web pages?

- Current approach is to provide a “Show me a web page” button
  - Makes this type of feedback different than help

Screen shot of WEBsistments



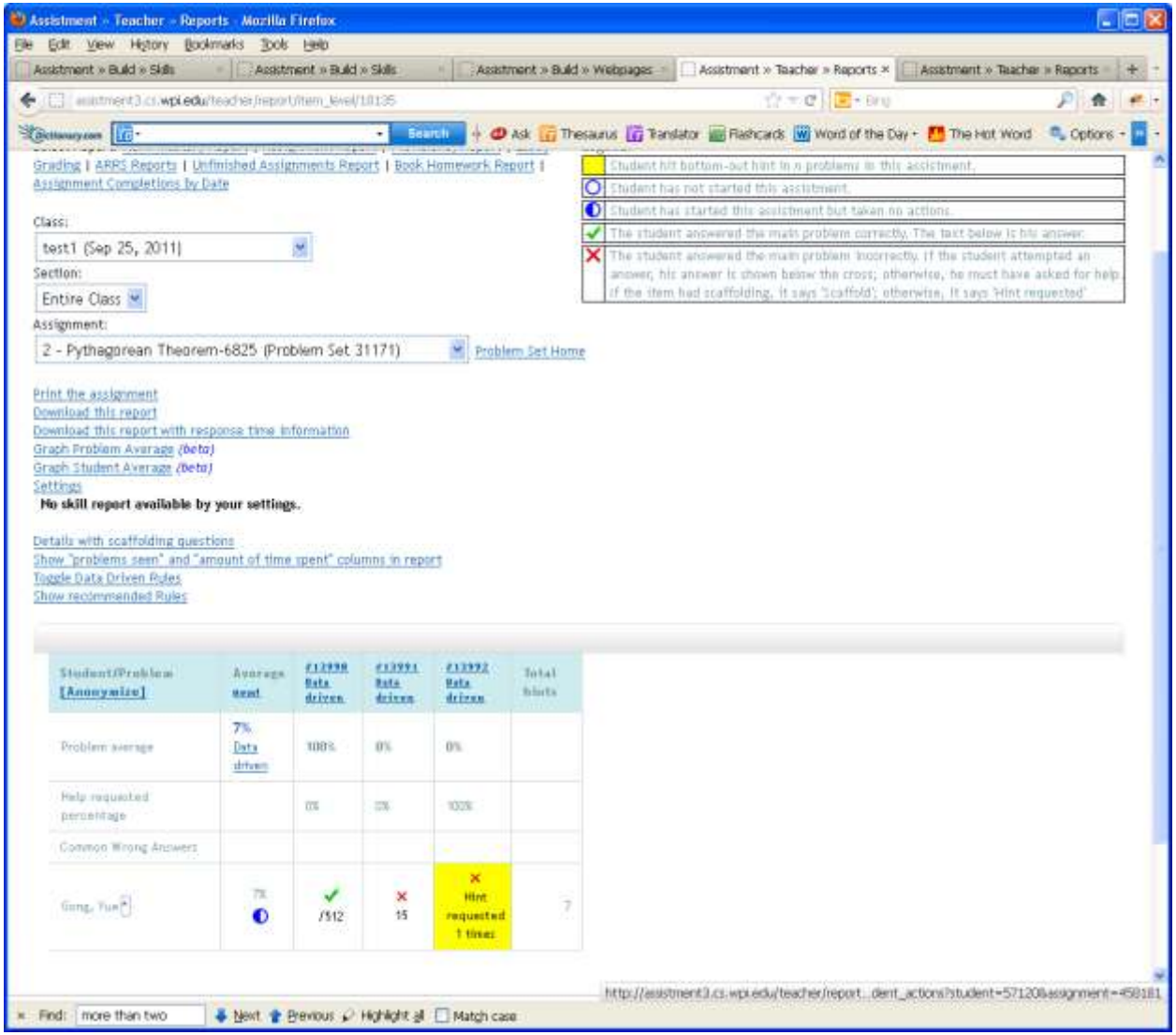
Give students a survey on web page when they finish with it



#3: When to present web pages?

- Current approach is to provide a “Show me a web page” button
  - Makes this type of feedback different than help
- Have been experimenting with not having web pages counted as “incorrect”
  - Motivate students to use them
  - Seems qualitatively different than help

Teachers can see student progress



Teachers can see how effective web pages are

Webpage Report for Skill "Equation Solving More Than Two Steps".

Show webpage info

URL	Description	Times Shown	Correct On Next Action	Correct On Next Problem	Average View Time	Student Ratings (Bad (1) - Good (3))
http://www.purplemath.com/modules/solvelin3.htm	solving multi-step linear equations	24	Correct: 5 (21 %) No Response: 0	Correct: 14 (58 %) No Response: 0	51.3 s	Average Rating: 1.5 (8 technical difficultie
http://www.purplemath.com/modules/solvquad.htm	solving quadratic equations	19	Correct: 7 (37 %) No Response: 0	Correct: 10 (53 %) No Response: 0	51.0 s	Average Rating: 1.3 (6 technical difficultie
http://www.purplemath.com/modules/solvelin4.htm	solving multi-step linear equations, with parentheses	35	Correct: 13 (37 %) No Response: 0	Correct: 20 (57 %) No Response: 0	33.2 s	Average Rating: 1.7 (3 technical difficultie
http://www.schooltube.com/video/abd830100f0d4c25aaba/Solving-Equations	video: solving multi-step linear equations	19	Correct: 6 (35 %) No Response: 2	Correct: 11 (61 %) No Response: 1	83.1 s	Average Rating: 1.3 (7 technical difficultie
http://www.sosmath.com/algebra/solve/solve0/solve0.html	solving multistep equations	22	Correct: 8 (36 %) No Response: 0	Correct: 10 (45 %) No Response: 0	40.1 s	Average Rating: 1.3 (6 technical difficultie
http://www.youtube.com/watch?v=DhikunZD0Ms	Solving Equations with Variables on Both Sides(A)	30	Correct: 15 (50 %) No Response: 0	Correct: 15 (54 %) No Response: 2	65.3 s	Average Rating: 1.8 (5 technical difficultie
http://www.youtube.com/watch?v=K2X5O0-nwJ8	Solving Mutli-Step Equations with Variables on one Side of the Equation(A)	23	Correct: 11 (48 %) No Response: 0	Correct: 9 (41 %) No Response: 1	59.8 s	Average Rating: 2.1 (3 technical difficultie
http://www.mathops.com/free/a1eq006.php	Solving Equations by Combining Like Terms(A)	106	Correct: 32 (31 %) No Response: 2	Correct: 49 (49 %) No Response: 6	66.1 s	Average Rating: 1.8 (13 technical difficultie

#3: When to present web pages?

- Current approach is to provide a “Show me a web page” button
  - Makes this type of feedback different than help
- Have been experimenting with not having web pages counted as “incorrect”
  - Asking for a web page seems qualitatively different
  - If you get it right, probably because you know it

Recap

- Find web pages project staff and teachers like
- Link a few web pages to each skill
- When problem is presented, student can get web page that teaches the associated skill
- Does it work?

Evaluation: counting approach

- Sequence of problems P1, P2
  - Consider cases where student gets P1 incorrect
- Why focus on cases where P1 is incorrect?

An odd effect

- If we look at all problems, we find that students who request a web page on P1 do worse on P2
  - Why?

Selection bias

- If we look at all problems, we find that students who request a web page on P1 do worse on P2
- Students who need to see a web page are systematically weaker than those who do not
- Even after instruction will still be weaker students

Evaluation: counting approach

- Sequence of problems P1, P2
  - Consider cases where student gets P1 incorrect
- Compute P2 – P1
  - For cases where student saw web page on P1 vs. no web page
- Really a bit trickier—did:

  (P2 – average on P2) – (P1 – average on P1)

Example

- Problem 1 (P1)
  - 38% of students answer correctly
  - Student got it wrong
- Problem 2 (P2)
  - 64% of students answer correctly
  - Student got it right
- Score = (P2 - %P2) – (P1 - %P1)

  $(1 – 0.64) – (0 – 0.38) = 0.36 – (-0.38) = 0.74$

Results:
mean gain score and 95% CI

	Saw web page	Did not see web page
Overall	0.50 ± 0.01	0.40 ± 0.01
No bottom-out hint	0.60 ± 0.02	0.49 ± 0.01
Bottom-out hint	0.41 ± 0.02	0.26 ± 0.01

Numbers are gain score from P1 to P2 adjusted by item difficulty

Overall an improvement when seeing a web page

	Saw web page	Did not see web page
Overall	0.50 ± 0.01	0.40 ± 0.01
No bottom-out hint	0.60 ± 0.02	0.49 ± 0.01
Bottom-out hint	0.41 ± 0.02	0.26 ± 0.01

Improvement independent of bottom-out hinting

	Saw web page	Did not see web page
Overall	0.50 ± 0.01	0.40 ± 0.01
No bottom-out hint	0.60 ± 0.02	0.49 ± 0.01
Bottom-out hint	0.41 ± 0.02	0.26 ± 0.01

Requiring a bottom-out hint is a marker of a struggling student

Weird result: student with web page more likely to bottom-out hint

	Saw web page	Did not see web page
Overall	0.50 ± 0.01	0.40 ± 0.01
No bottom-out hint	0.60 ± 0.02 **518**	0.49 ± 0.01 **5336**
Bottom-out hint	0.41 ± 0.02 **586**	0.26 ± 0.01 **3543**

(added counts to the table)

53% bottom out hint rate for seeing web page
40% bottom out hint rate for no web page

But web group showed more learning

Unclear why difference exists

	Saw web page	Did not see web page
Overall	0.50 ± 0.01	0.40 ± 0.01
No bottom-out hint	0.60 ± 0.02 **518**	0.49 ± 0.01 **5336**
Bottom-out hint	0.41 ± 0.02 **586**	0.26 ± 0.01 **3543**

Students who asked for web pages were weaker?

Students confused by web pages?

Concerns

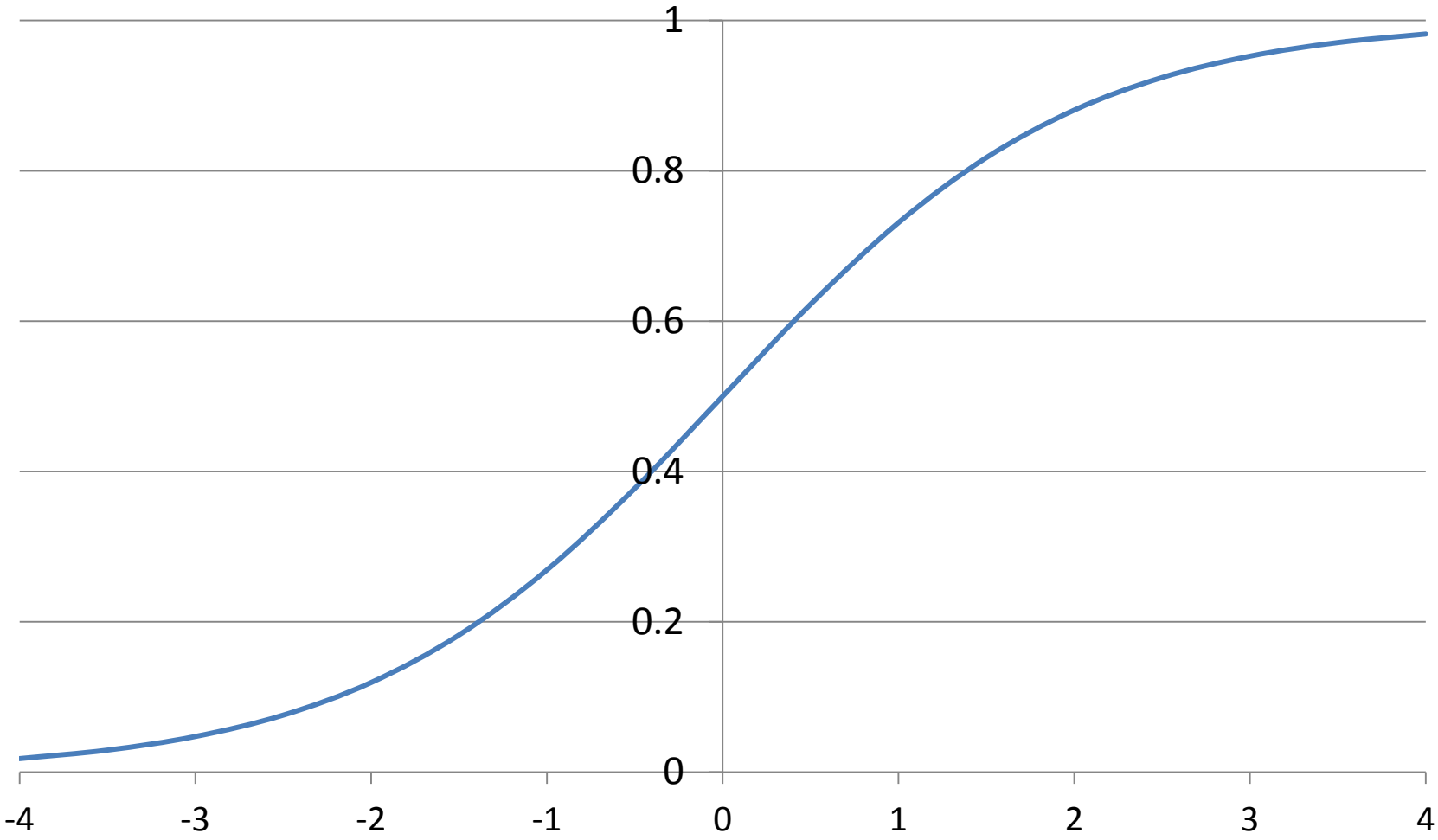
- Counting approach a bit crude
- Ignores prior performance (just P1)

Approach #2: logistic regression model

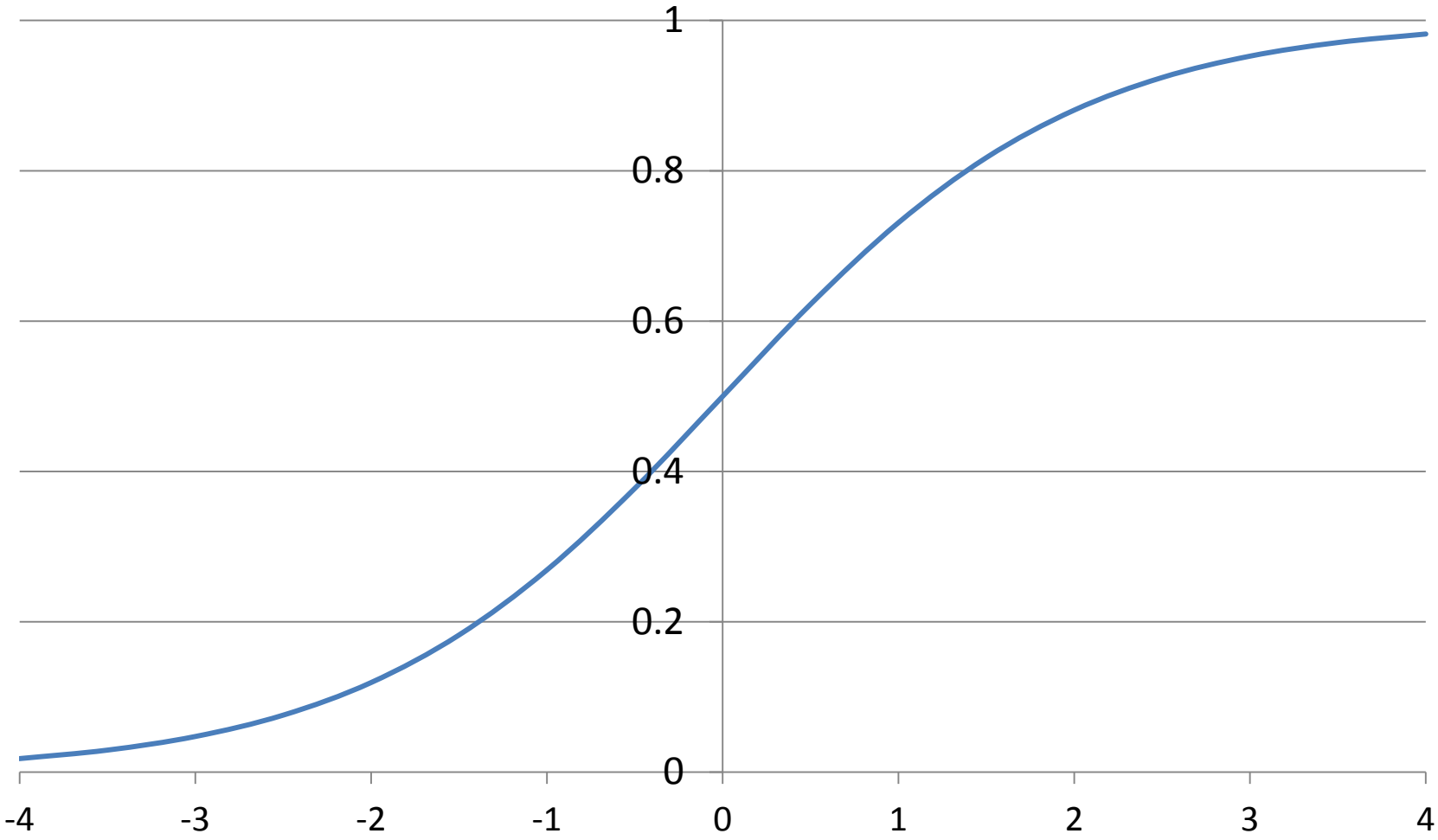
- Logistic regression is a great tool for analyzing binary outcome data

- Prediction = logistic(linear model(x1, x2, …))
  - It builds a linear model, then scales predictions to be between 0 and 1

Logistic graph



Apply linear regression (x-axis)
Then apply logistic transform



Logistic model

- Dependent: did student respond correctly?
- Independents:
  - Saw a web page on P1
  - Saw a web page on P2
  - Problem easiness of P1 (% correct)
  - Problem easiness of P2 (% correct)
  - Number of correct problems on this skill
  - Number of incorrect problems on this skill
  - Reached bottom-out hint in P1

Results

Independent variable	*B* (higher is more likely to get correct)
Saw a web page in P_1	0.393
Saw a web page in P_2	-1.693
Problem easiness of P_1	-0.983
Problem easiness of P_2	4.808
Number of prior corrects on the skill	0.010
Number of prior incorrects on the skill	-0.023
Reached the bottom-out hint in P_1	-0.635

Seeing a web page still helps

Independent variable	*B* (higher is more likely to get correct)
Saw a web page in P_1	0.393
Saw a web page in P_2	-1.693
Problem easiness of P_1	-0.983
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Reached the bottom-out hint in P_1	-0.635

If they didn't understand on P1, more web pages is a bad sign

Independent variable	*B* (higher is more likely to get correct)
Saw a web page in P_1	0.393
Saw a web page in P_2	-1.693
Problem easiness of P_1	-0.983
Problem easiness of P_2	4.808
Number of prior corrects on the skill	0.010
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Reached the bottom-out hint in P_1	-0.635

Hard issue: evidence vs. causality for web pages

Working on an easier problem seems to hurt later performance (neat)

Independent variable	*B* (higher is more likely to get correct)
Saw a web page in P_1	0.393
Saw a web page in P_2	-1.693
Problem easiness of P_1	-0.983
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Number of prior corrects on the skill	0.010
Number of prior incorrects on the skill	-0.023
Reached the bottom-out hint in P_1	-0.635

Prior performance does what's expected

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Saw a web page in P_1	0.393
Saw a web page in P_2	-1.693
Problem easiness of P_1	-0.983
Problem easiness of P_2	4.808
Number of prior corrects on the skill	0.010
Number of prior incorrects on the skill	-0.023
Reached the bottom-out hint in P_1	-0.635

Students who need to be told the answer do poorly on later problems

Independent variable	*B* (higher is more likely to get correct)
Saw a web page in P_1	0.393
Saw a web page in P_2	-1.693
Problem easiness of P_1	-0.983
Problem easiness of P_2	4.808
Number of prior corrects on the skill	0.010
Number of prior incorrects on the skill	-0.023
Reached the bottom-out hint in P_1	-0.635

Major concern

- Students who are seeing a web page have **opted in** to seeing it
  - Not a random assignment!
  - These students could be more motivated

- But, control for several aspects of student knowledge/performance with regression models

PFA model and **hinting behavior** that control for student differences

Independent variable	*B* (higher is more likely to get correct)
Saw a web page in P_1	0.393
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Problem easiness of P_1	-0.983
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Major concern

- Students who are seeing a web page have opted in to seeing it
  - Not a random assignment!
  - These students could be more motivated
- But, control for several aspects of student knowledge/performance with regression models
  - Could still be unaccounted for factors that are skewing the results (sorry if you were a reviewer)

Discussion: how to simplify analysis

- Problem is that students are able to select when to see a web page
- What if we take this decision out of student hands?
  - Present web page on student mistakes
  - Or when student is likely to *thrash*
  - Or… ???
- What will students tolerate?

Simple question: what are properties of a good web page?

- **Length.** A 30-minute page will do a good job of teaching, but bore students to tears

- **Type**. Some pages are videos, others are manipulables, others are text-based
  - Is video really better for teaching?

What is goal of web pages?

- Are web pages a refresher for students who forgot the skill?
  - Or for students who never received instruction?
  - Do students who received but did not understand instruction different?

- Suspect different types of learner needs
  - But, how to characterize students? Low/high knowledge, starting out on skill vs. persistent failure, knowledge of other skills, knowledge on prerequisite skills

What is model for ITS?

- Declarative lecture in class, then practice at home?

- How about watch video lecture at home and do some sample problems
  - Cover tricky problems in class

- “Flipping the classroom”

What is the goal of our search for good web pages?

What is the goal of our search for good web pages?

- Have the collection of web pages presented to students be as effective as possible

- Not: find the best web page
- Definitely not: accurately estimate how effective every web page
  - We don't have enough students (and the web keeps growing!)

How should we select which web page to present? (for now it's just random)

- Goal is to find very good (ideally the best) web pages in our collection
  - Without subjecting students to seeing too many bad pages

- The goal is **not** to run a t-test and compare every page → if page looks likely to be bad, can drop it

- Decision theoretic framework seems very applicable here

Decision theory

- Looks at benefits of exploration (trying out options that appear suboptimal to see if they really are suboptimal) vs. exploiting what is known

- Showing a sub-optimal web page
  - Can estimate negative impact on this student
  - Look at probability of it being a strong page and look at future positive impact on other students

- Interesting experimental ethics issues

Experimental ethics

- Experimenters should minimize harm to subjects
- Isn't testing web pages potentially harmful
  - At least relative to *known* best web page?
- How to quantify? How to balance harm to this subject vs. benefit to others?
- Hard to justify running a fixed number of trials on each web page

What is a good outcome measure?

- Performance on the current problem
  - Not a great measure of learning (too short term)
  - But if web page cannot improve performance there, is probably bad (Ken Koedinger)
- Performance on the next problem (a bit better)
- Would like to create something with learning curves and see how much learning a web page is worth

What are other sources of data?

- Can be difficult to properly evaluate a web page (need a large number of students)
- Don’t want students to spend time on pages that are likely to be bad
- Is there a less formal way of evaluating pages?

Webpages with skill "Equation Solving More Than Two Steps".

how detailed report

URL	Descriptions	Average Teacher Ratings (Bad (1) - Good (3))	My Rating:	
http://www.purplemath.com/modules/solvelin3.htm	solving multi-step linear equations	0.0 (0 teacher ratings)		☐ Has video ☐ Has flash ☐ Has audio ☐ Enabled ☐ Is WPI certified Save Changes
http://www.purplemath.com/modules/solvquad.htm	solving quadratic equations	0.0 (0 teacher ratings)	Bad / Okay / Good	☐ Has video ☐ Has flash ☐ Has audio ☐ Enabled ☐ Is WPI certified Save Changes
http://www.purplemath.com/modules/solvelin4.htm	solving multi-step linear equations, with parentheses	0.0 (0 teacher ratings)		☐ Has video ☐ Has flash ☐ Has audio ☐ Enabled ☐ Is WPI certified Save Changes
http://www.schooltube.com/video/abd830100f0d4c25aaba/Solving-Equations	video: solving multi-step linear equations	0.0 (0 teacher ratings)		☐ Has video ☐ Has flash ☐ Has audio ☐ Enabled ☐ Is WPI certified Save Changes
http://www.sosmath.com/algebra/solve/solve0/solve0.html	solving multistep equations	0.0 (0 teacher ratings)		☐ Has video ☐ Has flash ☐ Has audio ☐ Enabled ☐ Is WPI certified Save Changes
http://www.youtube.com/watch?v=DhikunZD0Ms	Solving Equations with Variables on Both Sides(A)	0.0 (0 teacher ratings)		☑ Has video ☐ Has flash ☑ Has audio ☑ Enabled ☐ Is WPI certified Save Changes
http://www.youtube.com/watch?v=K2X5O0-nwJ8	Solving Mutli-Step Equations with Variables on one Side of the Equation(A)	0.0 (0 teacher ratings)		☑ Has video ☐ Has flash ☑ Has audio ☐ Enabled ☑ Is WPI certified Save Changes
http://www.mathops.com/free/a1eq006.php	Solving Equations by Combining Like Terms(A)	0.0 (0 teacher ratings)		☐ Has video ☐ Has flash ☑ Has audio ☑ Enabled ☑ Is WPI certified Save Changes

dd a new webpage

Why am I excited about this topic?

- Greatly extends scope and capabilities of computer tutors
  - Without much cost

- Creates a couple of interesting future directions
  - EdRank: how to automatically sort web pages by educational efficacy
  - Virtual ASSISTment Laboratory (VAL): enabling other researchers to run experiments inside of our tutor

ASSISTments

- http://assistments.org/
- http://teacherwiki.assistment.org/

Game-like elements

- Wayang outpost (UMASS Amherst)
- Monkey's Revenge (www.gltutors.com)