

More Data, Better Learning? A Balanced Look at Adaptive Learning Systems

Lisa Spiro
"IB in a Virtual World"
October 5, 2013



How can we know what students know (and thus help them learn)?



[Timothy Dilich](#)

How can we teach students with diverse knowledge and backgrounds?



[Diversity in Media Ownership](#)

Using Adaptive Learning Systems to Monitor and Personalize Learning

“*adaptive learning* takes a sophisticated, data-driven, and in some cases, non-linear approach to instruction and remediation, adjusting to a learner’s interactions and demonstrated performance level and subsequently anticipating what types of content and resources learners’ need at a specific point in time to make progress.” ([Learning to Adapt](#))

Forms of Adaptive Learning

- Clickers/ audience response systems (e.g. [Contingent Pedagogies](#))
- Games (e.g. [Refraction](#))
- [Textbooks](#)
- [Computer Adaptive Testing](#)
- **Intelligent tutoring systems/ cognitive tutors**

Some See Adaptive Learning As A Way to Improve and Personalize Learning


“Adaptive learning may prove to be exactly what we need most right now – practices and tools that enable maximum learning gains for a diverse and broad array of students irrespective of their prior educational performance and preparation.”

(Josh Jarrett and Rahim Rajan, [Gates Foundation](#))

- >> Gates recently issued an [RFP](#) for “Adaptive Learning Market Acceleration Program”

But Others Worry That Adaptive Learning Is Reductive and Dehumanizing

“Computer adaptive learning systems are reductionist and primarily attend to those things that can be easily digitized and tested (math, science and reading). They fail to recognize that high quality learning environments are deeply relational, humanistic, creative, socially constructed, active and inquiry-oriented.” ([Philip McRae](#))



How do we make
sense of this debate?

Navigating the Territory: Map for Today's Talk

- I. Understanding adaptive learning systems
- II. Case studies of 3 high profile adaptive learning systems
 - I. Carnegie Cognitive Tutor
 - II. Open Learning Initiative
 - III. Khan Academy
- III. Making an informed decision
 - I. Benefits, challenges & risks



<http://www.flickr.com/photos/electrichamster/96531540/>

I. Understanding Adaptive Learning Systems



Thinking designed by Hedi Assadi Joulaee
from The Noun Project

How do students learn best?

1. **Conventional class** with 30 students
2. **Mastery learning**: students master material through formative tests, feedback and correction
3. **Tutoring for 1-3 students**, followed by formative tests, feedback and correction

“The Two Sigma Problem”: [Bloom](#) (1984) on the Benefits of Tutoring

Type of Learning	Results
Conventional class	--
Mastery learning	1 std. deviation (average student above 84% of students in conventional class)
Tutoring	2 std. deviation (average student above 98% of students in conventional class)

How might we scale the effectiveness of tutoring without facing the high costs?

Intelligent Tutoring Systems as One Solution to the Scale Problem

Type of Learning	Results
Human Tutoring	.79 standard deviation
Step-based intelligent tutoring systems	.76 standard deviation (sigma)

[VanLehn \(2011\)](#)

Two key differentiators of human tutors & intelligent tutoring systems (VanLehn):

- **Feedback:** tutors help students identify errors and correct them
- **Scaffolding:** tutors help students think through problems, take on increasing responsibility

ICAP Hypothesis For Differentiating Levels of Engagement in Instruction (Chi)

interactive ≥ constructive > active > passive

Interactive: dialoguing with peer or expert

Constructive: producing outputs, e.g. concept map, hypothesis, questions

Active: “doing something,” e.g. highlighting, pointing

Passive: listening to a lecture

What Are Intelligent Tutoring Systems?

- “computer software designed to simulate a human tutor’s behavior and guidance.” ([ELI](#))
- Based on research into artificial intelligence
- Provide exercises until mastery is demonstrated
- Offer customized instruction and feedback
- Collect detailed data about the learner
- [Enable](#)
 - Students to learn at their own pace
 - Instructors to monitor learning & intervene

II. Case Studies of Technologies Incorporating Adaptive Learning



1. Carnegie Cognitive Tutor



Overview of the Carnegie Cognitive Tutor

- Based on the [ACT-R](#) theory of knowledge (“learning by doing”)
- [Grew out](#) of Pittsburgh Urban Mathematics Project [Algebra Tutor](#) (early 1990s)
- “Model tracing” tracks student’s steps in problem solving and provides feedback
- “Knowledge tracing” monitors learning across problems to select next problems
- Supports:
 - Mastery learning
 - Differentiation of instruction

Multiple Representations to Support Different Learning Styles

Carnegie Learning Algebra I

File Edit Options View Help

10 - Linear Models and Four-Quadrant Graphs

1 - Working with Positive Integer Rates of Change

Michelle Kelly

100%

Examples Next Home

Table of Contents Lessons Progress

Summary

You are going to buy a bicycle. You have \$20, and each day you are able to save \$2.

1. How many more days must you save to buy a bike that costs \$60?

2. How much money will you have saved 20 days from now?

3. If you saved your money at this rate to get your initial savings of ten dollars, how many days ago did you start to save?

4. In two weeks and three days from now, how much money will you have saved?

To write an expression, define a variable for the time from now at which you have saved money and use this variable to write a rule for your savings.

Worksheet

Quantity Name	the time from now	savings
Rate	days	dollars
Expression	x	$2.00x + 10.00$
Question 1	20	50.00
Question 2	20	50.00
Question 3	-5	0.00
Question 4	17	44.00

Grapher

Open LHP

X Interval: 1 Y Interval: 10

Savings (dollars)

Time (days)

Just in Time Feedback

Michelle Kelly
Feb 01

Solver Glossary Example

$2x$

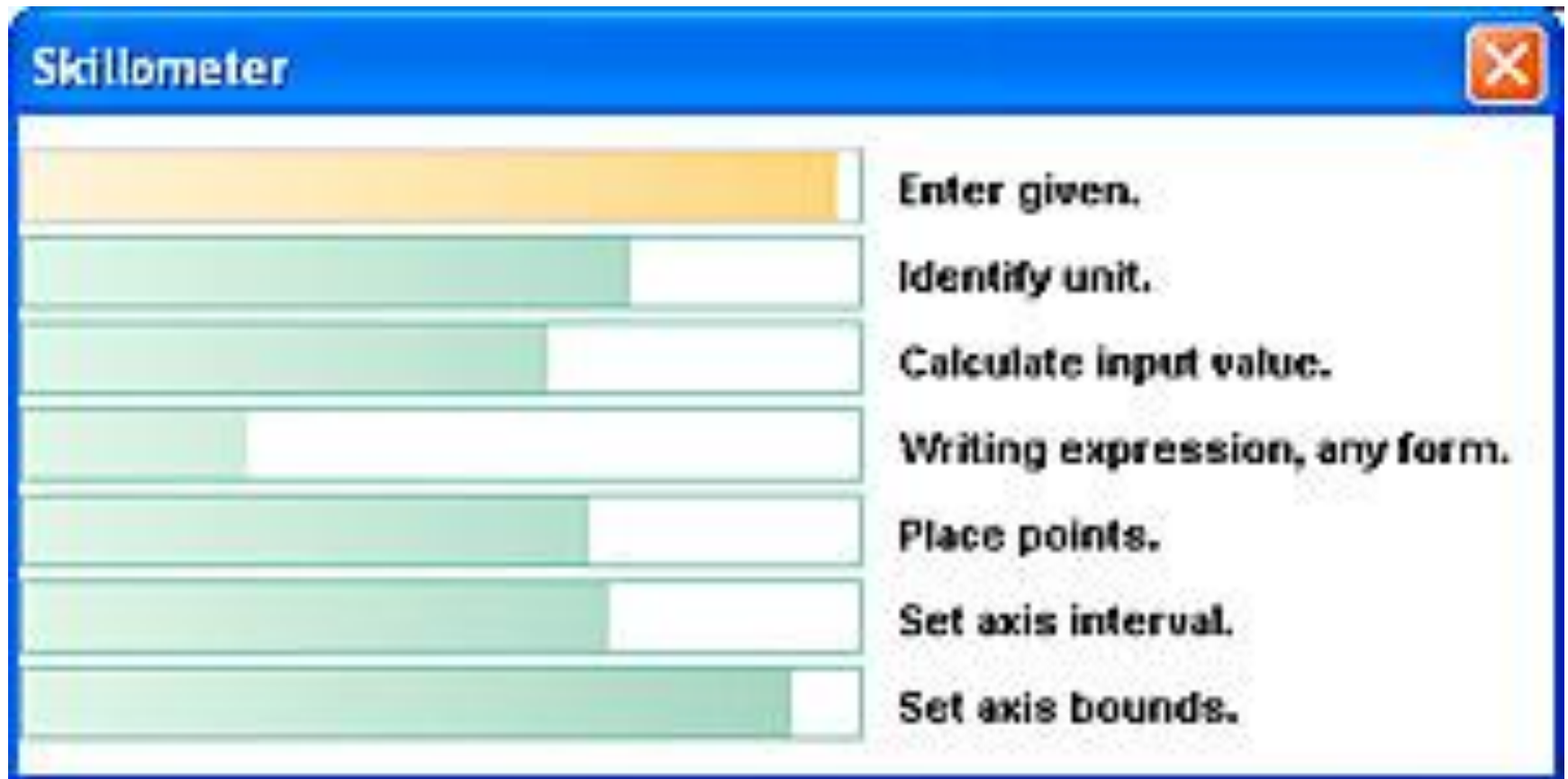
Your savings increases by 2 each day, but remember that it starts at 10 dollars.

Quantity Name	the time from now	savings
Unit	days	dollars
Expression	x	$2x$
Question 1		
Question 2		
Question 3		
Question 4		

Graph Point 1
Graph Point 2
Graph Point 3
Graph Point 4

Draw Line Interval 1.0 Y Interval 1.0

Skillometer (Assessment)



Teaching with Cognitive Tutor

Integrated approach: text, software, training

Recommendation: classes spend

- 2 days/week using the software
- 3 days/week in face-to-face class using active learning techniques, e.g. problem solving, group work

[Koedinger & Corbett, 2006](#)

Mixed Research Results on Cognitive Tutor from *What Works Clearinghouse*

- Out of 27 studies of *Carnegie Learning Curricula and Cognitive Tutor*, only 3 are fully eligible and 3 eligible with reservations
- High [standards](#) for eligibility, e.g. randomized controlled trial
- Found “mixed effects” on students’ math scores:
 - one study showed statistically significant positive effect on student performance
 - one (Geometry) a statistically significant negative effect
 - four showed indeterminate effects

U.S. Department of Education [What Works Clearinghouse](#). (2013). *High School Mathematics intervention report: Carnegie Learning Curricula and Cognitive Tutor*®

Positive Effects in *Large-Scale Effectiveness Trial of Cognitive Tutor Algebra I* ([RAND 2013](#))

Method:

- Randomized controlled effectiveness trial
- Involved 73 high schools and 74 middle schools
- Compared courses using Cognitive Tutor Algebra I (CTAI) + textbook to those using a traditional textbook

Findings: Use of CTAI led to

- “a significant positive effect in high schools in the second year of implementation” (but not in the first year)
- “equivalent to moving an algebra I student from the 50th to the 58th percentile”

Cf. [Reich](#)

2. Open Learning Initiative

Carnegie Mellon University



Open Learning Initiative

Transforming higher education through the science of learning.

Overview of the Open Learning Initiative

- Initiative launched by Carnegie Mellon U in 2002
- Open educational project (free/ low-cost access)
- Focused on college and [community college](#) courses such as statistics, chemistry, French & economics (18 to date)
- Incorporates embedded “mini-tutors”: simple versions of cognitive tutors to provide feedback & assessment
- Collaboratively designed by subject experts, cognitive scientists, human-computer interaction experts, &c
- Collects granular data on learning
- Provides feedback to learners and instructors

Understanding the Structure of the Course and Learning Objectives

Module 1 / Examining Distributions

LEARNING OBJECTIVES

Summarize and describe the distribution of a categorical variable in context.

Generate and interpret several different graphical displays of the distribution of a quantitative variable (histogram, stemplot, boxplot).

Summarize and describe the distribution of a quantitative variable in context: a) describe the overall pattern, b) describe striking deviations from the pattern.

Relate measures of center and spread to the shape of the distribution, and choose the appropriate measures in different contexts.

Compare and contrast distributions (of quantitative data) from two or more groups, and produce a brief summary, interpreting your findings in context.

Apply the standard deviation rule to the special case of distributions having the "normal" shape.

Self-Assessment/ Metacognition through “Did I Get This?”

did I get this

Here are the number of hours that 9 students spend on the computer on a typical day:

1 6 7 5 5 8 11 12 15

The mode number of hours spent on the computer is:

The data from the above 9 students forms a distribution.



Incorrect. Bimodal distributions contain two modes. Since there is only one mode, what type of distribution is it?

Tracking Student Learning via the Learning Dashboard

Module 2
Examining Relationships

View data for All Students [> Hide Options...] EMAIL

All Students Individual Student

ESTIMATED LEARNING LEVEL Learning Objectives

Classify a data analysis situation (involving two variables) according to the "role-type classification," and state the appropriate display and/or numerical measures that should be used in order to summarize the data. [> Hide Details...]

Estimated Learning by Student 43 students
1 dot = 3 students

Class Accuracy by Sub-Objective

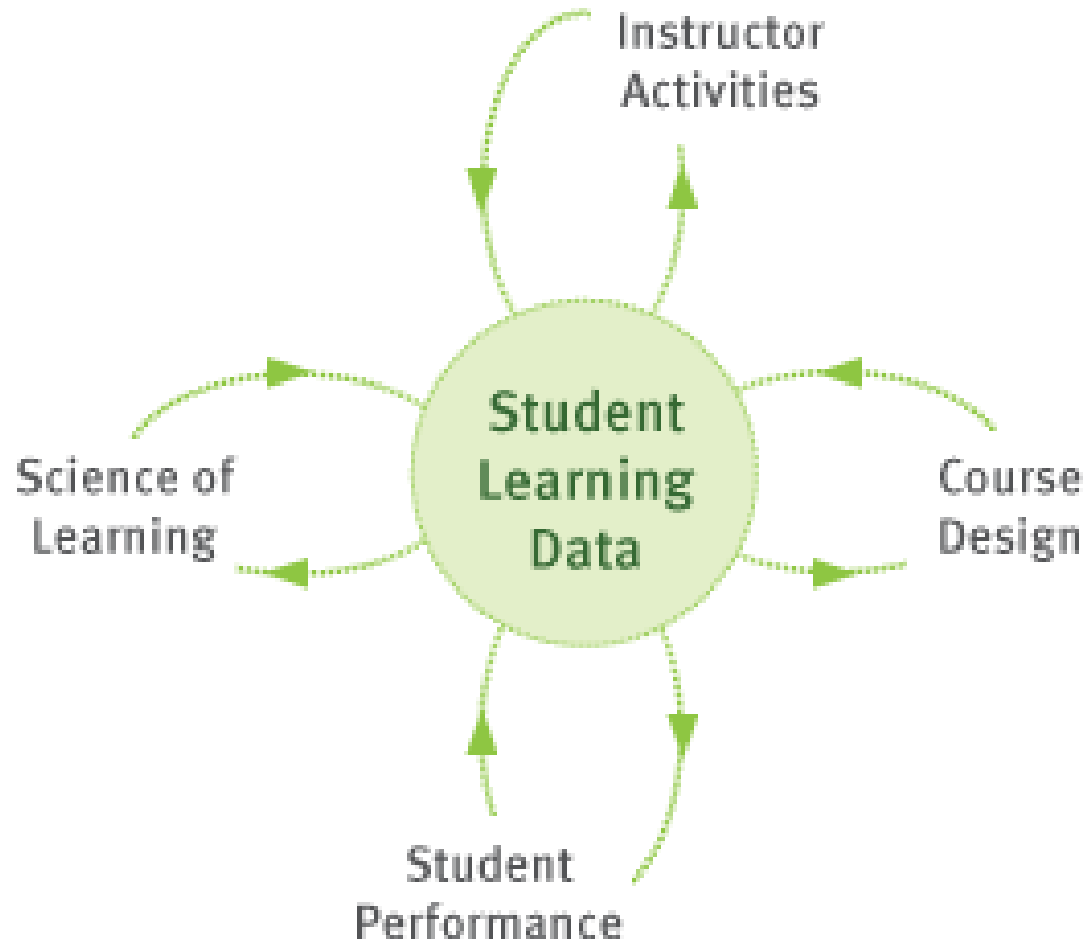
Sub-Objective	% correct
Categorical vs...	27
Explanatory vs...	27
Identifying case C → C...	31
Select appropriate...	13
Select appropriate...	13

Compare and contrast distributions (of quantitative data) from two or more groups, and produce a brief summary, interpreting your findings in context. [> Show Details...]

Produce a two-way table, and interpret the information stored in it about the association between two categorical variables by comparing conditional percentages. [> Show Details...]

Graphically display the relationship between two quantitative variables and describe: a) the overall pattern, and b) striking deviations from the pattern. [> Show Details...]

“Data Collection and Feedback Loops for Continuous Improvement”



OLI Hybrid STATS Course Speeds Learning, Brings Equal or Better Performance

OLI Accelerated	Average % Correct	Traditional Control	Average % Correct
Pre	55	Pre	50
Post	73	Post	53
Increase: 18 percentage points		Increase: 3 percentage points	

Student performance on Comprehensive Assessment of Outcomes in a first [college-level] Statistics course

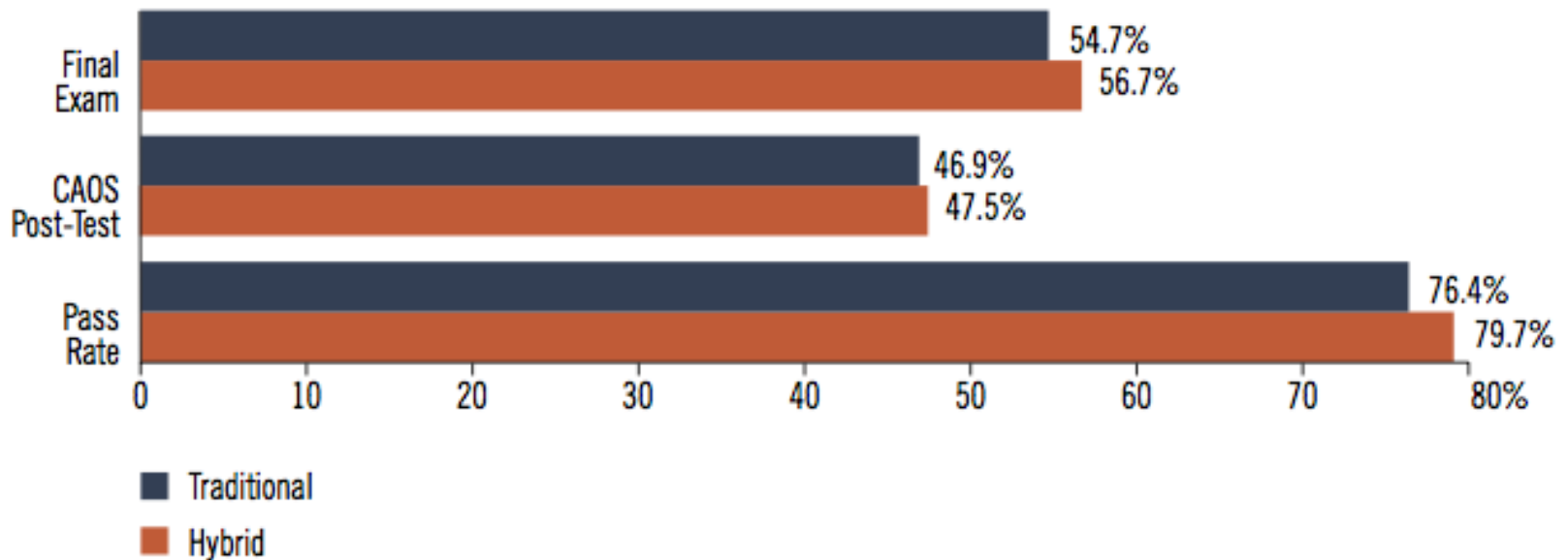
“students in OLI-Statistics took half the time to learn as much or more than their traditional counterparts”

Lovett, Marsha, Oded Meyer, and Candace Thille. [“The Open Learning Initiative: Measuring the Effectiveness of the OLI Statistics Course in Accelerating Student Learning.”](#) *Journal of Interactive Media in Education* 2008, no. 1 (2008).

Comparing Traditional & Hybrid STAT Courses at Public Universities

- “No significant difference” in learning outcomes
- Students had a slight preference for traditional
- Hybrid took ~ 25% less time to complete

Figure 1. Effect of Hybrid Format on Student Learning Outcomes



Bowen, William G, et al. [Interactive Learning Online at Public Universities: Evidence from Randomized Trials](#). Ithaca S+ R, 2012.

3. Adaptive Learning in the Khan Academy



Overview of Khan Academy

- Provides free access to educational materials, including videos, exercises, and assessment tools
- Founded 2006
- High level of use
 - 283 million [views](#) of YouTube channel
- Incorporates adaptive techniques
 - Creating a profile of the learner
 - Adjusting difficulty of exercises based on prior responses
 - Offering detailed assessment data to learner & coach

Exercises + Hints

Multiplication and division word problems 2

Get 5 correct in a row



Word problems with simple multiplication and division. Some problems have remainders.

Marvin the gnome is running from a big, mean orc. Marvin is 2 feet tall, and the orc is 8 feet tall.

The orc is how many times as tall as Marvin?

The orc is a lot taller than Marvin. We want to compare their heights using multiplication. How many times does 2 go into 8?



We can also write this as a multiplication problem.

$$2 \times ? = 8$$

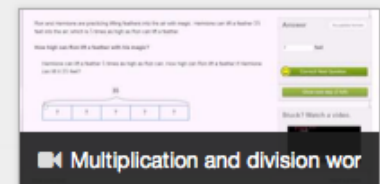
Answer

Acceptable formats

Check Answer

Show next hint (0 left)


Stuck? Watch a video.



Multiplication and division wor

Division word problem example 1


Monitor Your Own Learning

 LisaMSpiro

Learning Dashboard

ACCOMPLISHMENTS

 Badges

 Goals (beta)

VITAL STATISTICS

 Activity


 Focus

 **Skill Progress**

COMMUNITY

 Discussion

 Programs

 Coaches

LisaMSpiro » Skill Progress

Shows which skills you've worked on and completed.

Struggling Needs Practice Practiced Level One Level Two Mastered

Addition and subtraction

	Attempts	Correct	Progress
1-digit addition	14	93%	<input checked="" type="checkbox"/> Practiced
2-digit addition	0	—	<input checked="" type="checkbox"/> Practiced
1-digit subtraction	10	100%	<input checked="" type="checkbox"/> Practiced
2 and 3-digit subtraction	0	—	<input type="checkbox"/> Needs Practice
Addition with carrying	0	—	<input type="checkbox"/> Needs Practice
Addition and subtraction word problems	0	—	<input type="checkbox"/> Needs Practice
4-digit addition with carrying	0	—	<input type="checkbox"/> Needs Practice
Subtraction with borrowing	0	—	<input type="checkbox"/> Needs Practice
4-digit subtraction with borrowing	0	—	<input type="checkbox"/> Needs Practice

Multiplication and division

	Attempts	Correct	Progress
Number line 1	0	—	<input type="checkbox"/> Needs Practice
Multiplying 1-digit numbers	5	100%	<input checked="" type="checkbox"/> Practiced
Multiplying by multiples of 10	0	—	<input checked="" type="checkbox"/> Practiced

Provide Coaching

LEARN ▾ COACH **KHANACADEMY** Search LISAMSPIRO ▾

Class Roster **Student Progress** Skill Progress Grid Activity Real Time [Coach Resources](#)

Class: All students ▾ Activity from: Last 7 days ▾ Filter: Find topics or skills ▾ [Download](#) [Bookmark](#)

Student Name ^				Points
sammysj	1	0	0	725

sammysj [+ Make a recommendation](#)

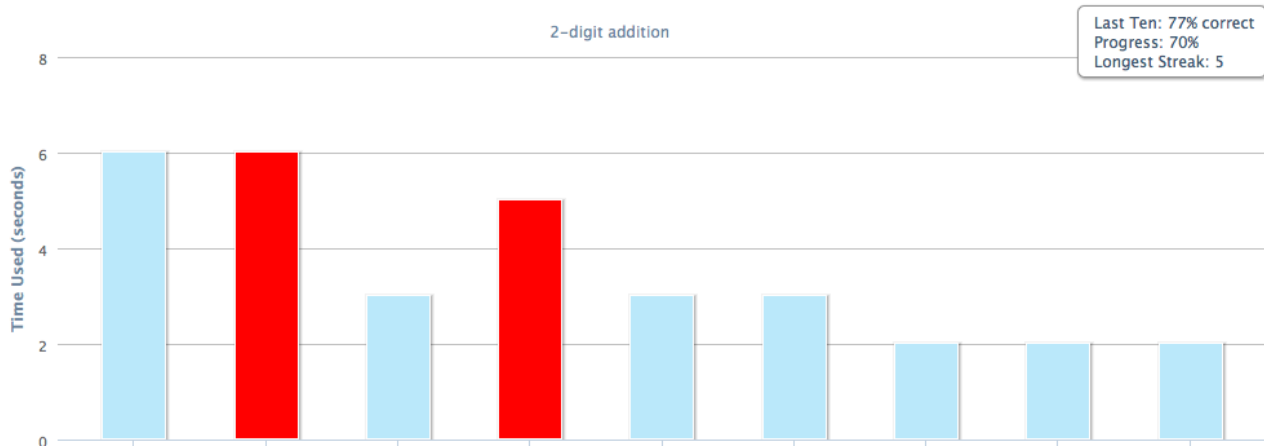
Exercises Recommendations Videos Badges Activity

<input type="checkbox"/> Practiced	Attempts	Correct	Progress
1-digit addition	0	—	0
2-digit addition	9	78%	1

sammysj » Problems » 2-digit Addition

[Make a recommendation](#)

Click a bar to view more detailed problem information.



Know What You Know: Khan Learning Flow

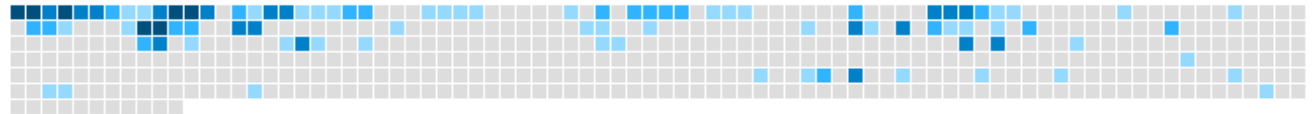
 LisaMSpiro

 0  0  0  0  1  3

8,937 energy points

The World of Math ▾

410



Converting mixed number
fractions

START

Next up...

Now you've unlocked your next set of tasks. We'll continue to fill these up and suggest new things to practice. Each one you finish will give you point rewards!

MASTERY
CHALLENGE
AVAILABLE!

START

UP NEXT

Reading pictographs 2

PRACTICE

YOU FINISHED!

Math Pretest

+1000 energy points

Preliminary Results of Khan Academy Blended Learning Experiments

- [Los Altos School District](#)
 - Blended learning model where Khan is just part of overall approach that also includes manipulatives, projects, etc.
 - More value in exercises & data than videos (best as supplement)
 - Increased student motivation & ownership
- [Envision Academy](#) (Oakland) small pilot
 - Enabled teacher to do more 1:1 & small group interactions
 - Teacher could examine learner data (but needed ask why)
 - Students appreciated instant feedback, became more responsible for learning, and coached each other
- SRI study due soon

Criticisms of Khan Academy

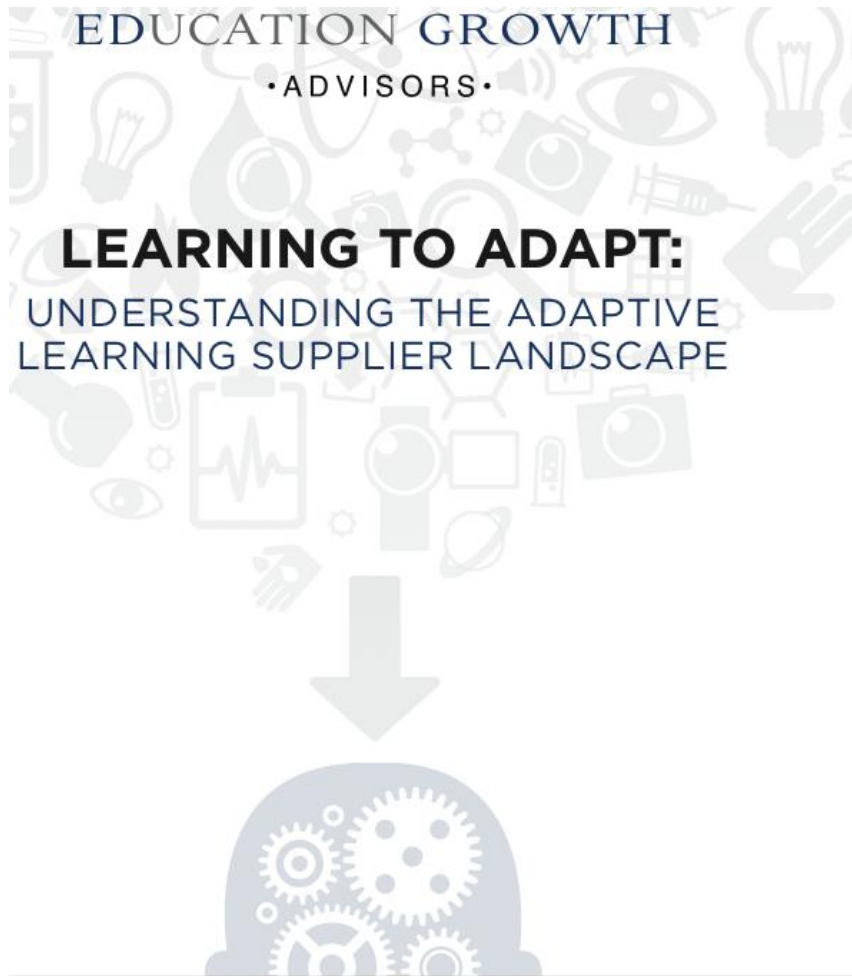
- “instructivist” approaches
- Inaccuracies in videos (Khan Mystery Science Theater)
- “do this then do this” pedagogy
- Distracting people from deeper problems with education, such as inequity

III. Evaluating Adaptive Learning



Employee Evaluation designed by Miroslav Koša from The Noun Project

Many Companies Are Developing Adaptive Learning Software, Including...



- Adapt Courseware
- Cerego Global
- CogBooks
- Jones & Bartlett Learning
- LoudCloud
- McGraw-Hill Education (LearnSmart)
- Open Learning Initiative
- Smart Sparrow

Advantages of Adaptive Learning Systems

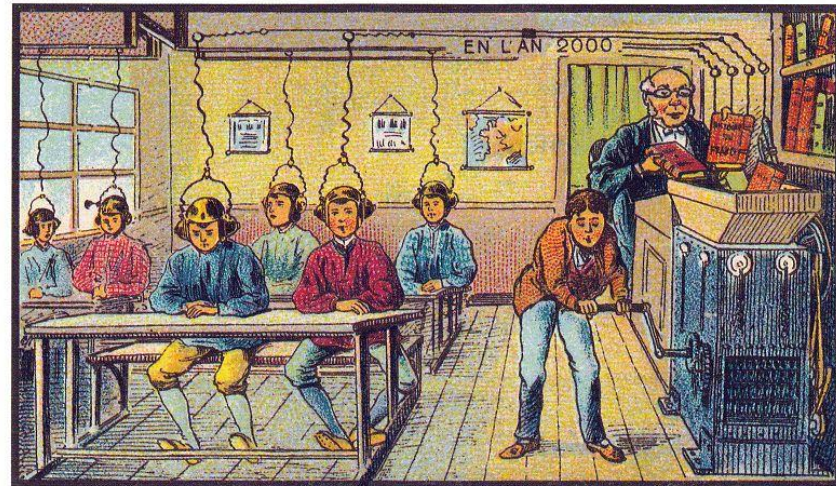
- Allow for personalized learning
- More scalable than human tutors
- Available at any time, any place
- May be easier for reserved students to interact with
- Create low-stakes opportunities to practice and build towards mastery
- Provide detailed data on learning that the instructor can use to tailor teaching

Limitations of Employing Adaptive Learning Systems

- Often require the learner to be motivated and self-directed
- Work best in areas where there are clear answers (procedural/ fact-driven)
- Expensive to develop
- Time to integrate into education: technical infrastructure, curriculum, teacher training
- Challenging for teachers to make sense of all the data
- We lack sufficient understanding of effectiveness and need better approaches to evidence (US Dept. of Education, 2013)

Concerns That Adaptive Learning Systems Undermine Learning

- Mechanizes learning
- At odds with creativity, choice & social relationships
- Diminishes teacher's autonomy
- Lack of clear research demonstrating benefits
- Enforces rigidity and conformity
- Too much screen time?



At School

[Wikimedia Commons](#)

Potential Costs Associated with Adaptive Learning Systems

- Software licenses
- Professional development
- Support
- Hardware
- Maintenance

Concerns about Commercializing and Privatizing Learning

- Cost of adaptive learning systems are often higher than traditional textbooks
- Do we want to outsource core learning functions to private companies?
- [Invest](#) in teachers rather than technology?
- [Lack of ownership](#) of subscription-based resources



[Stacks of pound coins](#)

Do we want to become the NSA of learning?

“The purpose of school isn't to get people comfortable with life under constant observation. The endless efforts at data collection to capture what ‘works’ with learning have the potential to disrupt the learning they are trying to capture. Learning requires trust...” ([Bill Fitzgerald](#))



Example of Privacy Concerns: inBloom

- Data that can be collected includes:
 - Social Security numbers
 - Disciplinary record
 - Whether a student is homeless
- Concerns about who can access the data:
 - Employers?
 - Marketers?
- inBloom responses:
 - Data is anonymized
 - Data will not be sold
 - School districts determine what data will be collected



Will Adaptive Learning Systems Replace Human Teachers?

- Most advocates of adaptive learning also emphasize the need for human teachers (cf. [VanLehn](#), [Meyer](#)/OLI, [Khan](#))
 - **Adaptive learning:** practice, hints, feedback, assessment, data on student performance
 - **Human teacher:** facilitating groups, helping students communicate, providing context, coaching, designing learning activities (but not grading tests)
- Adaptive learning is typically used in a blended setting
- But I could see a scenario where fewer teachers are required

Some Questions to Ask in Considering Adaptive Learning Systems

- Is this software consistent with the school mission and identity?
- How will parents respond? Students? Teachers?
- What evidence is there that this technology works?
- How will the software be integrated into the curriculum?
- How will teachers will be trained to use the software?
- What are the current and ongoing costs? What happens if the company goes out of business?
- Is there an adequate technical infrastructure (devices, networking, etc) to support the software?
- Who has [access](#) to student data? How will that data be protected?

Adaptive Learning Systems Bring Shifts In....

Category	Change
How class time is spent	Mix of computer-based interactions, individualized instruction & group work
Role of the teacher	Coach, learning designer, facilitator
Pace of learning	More according to the student's needs, not the school calendar

A Quick Poll: Raise your hand if...

- you think adaptive learning systems could improve learning
- you are concerned that adaptive learning systems could undermine learning
- you aren't sure what to think

A Scenario for Integrating Adaptive Learning into IB

“If... each student has his or her own computer and he/she does an online course which adapts to the level and needs of the student, there will be a much greater degree of differentiation. They are all doing mathematics, but one student is doing statistics, another is starting to look at the arithmetic mean ... The teacher is still needed though, to clarify concepts, to set creative open-ended problems and to ‘steer the ship’.” ([Dr Conrad Hughes](#), Director of Education in the International School of Geneva)

Leading Questions

- What impact might adaptive learning systems have on teaching and learning?
- What potential benefits do you see to adaptive learning systems? What about disadvantages?
- Are adaptive learning systems consistent with IB values?
- What strategy would you pursue with regards to adaptive learning systems? How would you explain this strategy to your teachers? Parents? Students? Board members?
- What are some effective approaches to differentiating instruction, with or without technology?

Download these slides

<http://digitalscholarship.wordpress.com/>

Digital Scholarship in the Humanities

Exploring the digital humanities

HOME

ABOUT

CV



Thanks!



Get in touch:
lisamspiro@gmail.com

[Namaste](#)

Resources

- Bloom, Benjamin S. "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring." *Educational Researcher* 13, no. 6 (June 1, 1984): 4–16. doi:10.3102/0013189X013006004.
- Education Growth Advisors, [Learning to Adapt](#) (2013)
- Fletcher, Seth. "How Big Data Is Taking Teachers Out of the Lecturing Business: Scientific American."
<http://www.scientificamerican.com/article.cfm?id=how-big-data-taking-teachers-out-lecturing-business>.
- Hanford, Emily, and Stephen Smith. "One Child at a Time: Custom Learning in the Digital Age." *American Radio Works*, August 2013.
<http://americanradioworks.publicradio.org/features/personalized-learning/>.

More Resources

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<http://www.joebower.org/2013/04/rebirth-of-teaching-machine-through.html>.
- US Department of Education, [*Expanding Evidence Approaches for Learning in a Digital World*](#) (2013)
- VanLehn, Kurt. "The Relative Effectiveness of Human Tutoring, Intelligent Tutoring Systems, and Other Tutoring Systems." *Educational Psychologist* 46, no. 4 (2011): 197–221.
- [What Works Clearinghouse](#)