

Learning Analytics Workshop

Evaluating New Approaches

Norman Bier

@normanbier

@cmuoli



**Open Learning
Initiative**

Carnegie Mellon University

March 18th, 2019



A challenge to higher education

“Improvement in post secondary education will require converting teaching from a solo sport to a community-based research activity.”

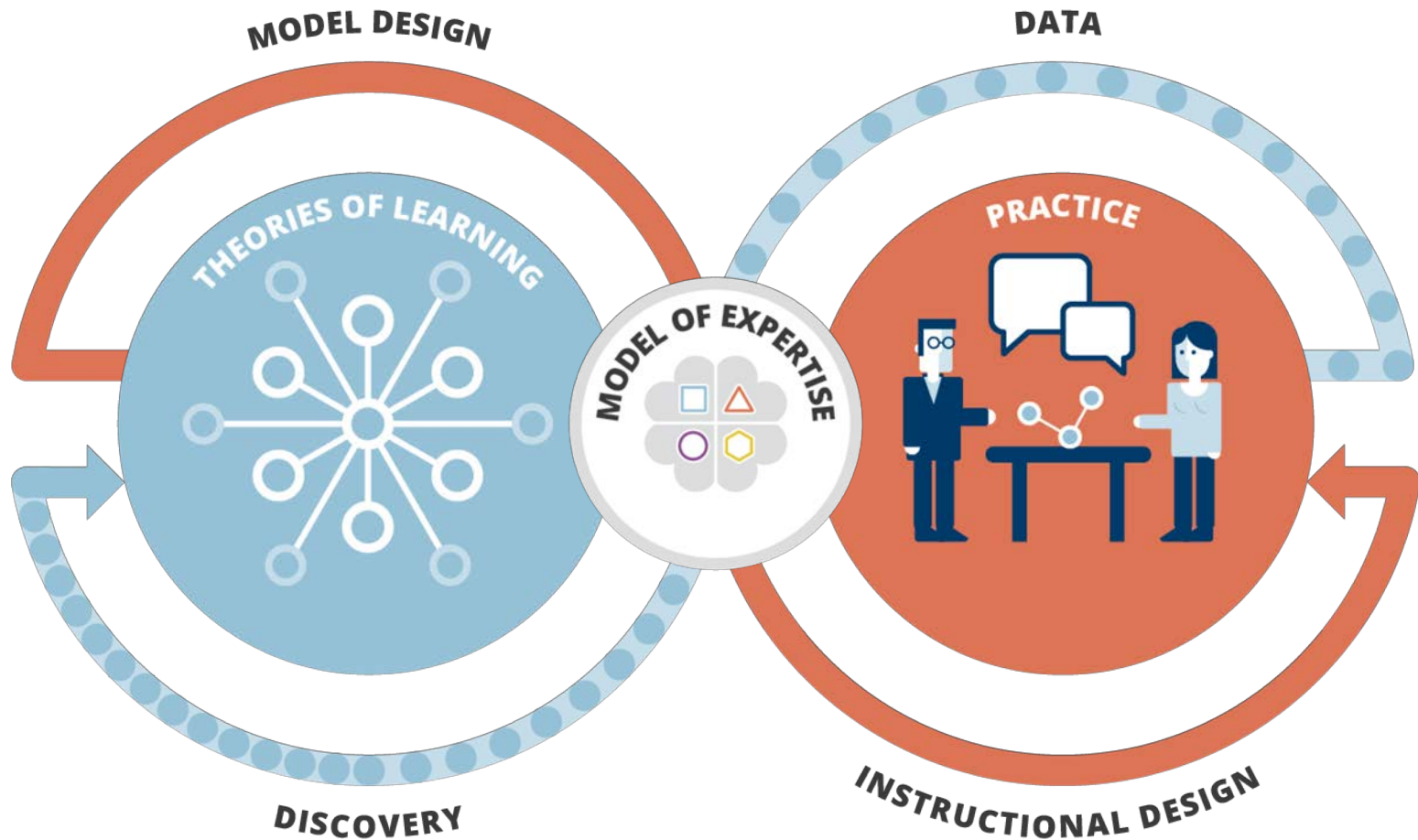
-Herbert Simon



Making learning something you can observe



The Simon Approach: Learning Engineering





Open Learning Initiative

Carnegie Mellon University



What is the Open Learning Initiative?

Scientifically-based online learning environments based on the **integration** of technology and the science of learning with teaching. OLI is **designed** to simultaneously improve learning and facilitate learning research.



The screenshot displays the OLI interface, which includes a chemistry lab setup window and a physics problem window.

Chemistry Lab Setup Window:

- Substance Explorer:** Lists various substances including $\text{1M NaH}_2\text{CH}_2\text{COO}$, 1M NaOH , 1M NaHCO_3 , $\text{1M NaHCO}_2\text{COO}$, 1M NaOH , and 1M NaOH .
- Workbench 1:** Shows a 10mL Pipet and a 10mL Beaker.
- Solution Info:** Name: 1M NaHCO_3 , Volume: 100.0 mL.
- Legend:** Aqueous (blue), Solid (red), Gas (green).
- Log Molarity:** A bar chart showing the concentration of various species.
- Species Table:**

Species	Molarity
H^+	$4.624\text{e-}9$
OH^-	$2.163\text{e-}6$
Na^+	$1.000\text{e}0$
HCO_3^-	$9.797\text{e-}1$
H_2CO_3	$1.015\text{e-}2$
CO_3^{2-}	$1.015\text{e-}2$

Physics Problem Window:

did I get this?

Determine the sum of three concurrent forces:

- Force F_1 has a magnitude of 5N; its line of action passes through points A (1, 1) and B (4, 3)
- Force F_2 has a magnitude of 5N; its line of action is parallel to a 3-4-5 triangle
- Force F_3 has a magnitude of 5N; its line of action is at 60 degrees to the horizontal

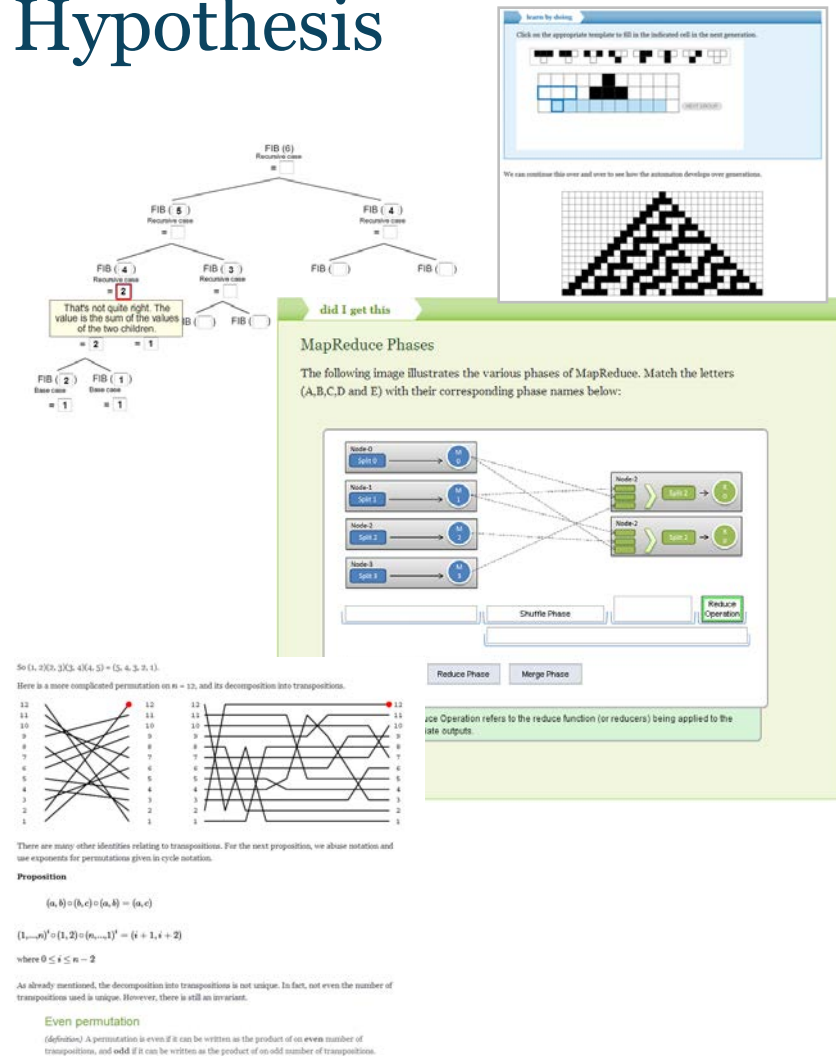
What is the magnitude of the sum?
 $R = 5.6$ N

What is the direction and the sense of the vector sum? Enter the positive angle α and then choose the correct quadrant:
 $\alpha =$ degrees

Hint: Since the purpose of this activity is self-assessment, you should try to work through this one on your own. However, if you're still unsure of the procedure, you can [click here](#) to expand the problem.



Learning Design As Hypothesis



Learn by doing

Click on the appropriate template to fill in the indicated cell in the next generation.

We can continue this error and even see how the automata develops over generations.

did I get this

MapReduce Phases

The following image illustrates the various phases of MapReduce. Match the letters (A,B,C,D and E) with their corresponding phase names below:

Node 0 Split 0 → Map 0 → Reduce 0

Node 1 Split 1 → Map 1 → Reduce 1

Node 2 Split 2 → Map 2 → Reduce 2

Node 3 Split 3 → Map 3 → Reduce 3

Shuffle Phase

Reduce Phase

Merge Phase

So $(1, 2)(3, 4)(5, 6) = (1, 2)(3, 4)(5, 6) = (1, 2)(3, 4)(5, 6)$.

Here is a more complicated permutation on $n = 12$, and its decomposition into transpositions.

There are many other identities relating to transpositions. For the next proposition, we abuse notation and use exponents for permutations given in cycle notation.

Proposition

$(a, b) = (b, a) = (a, b) = (a, b)$

$(1, 2)(3, 4) = (1, 2)(3, 4) = (1, 2)(3, 4)$

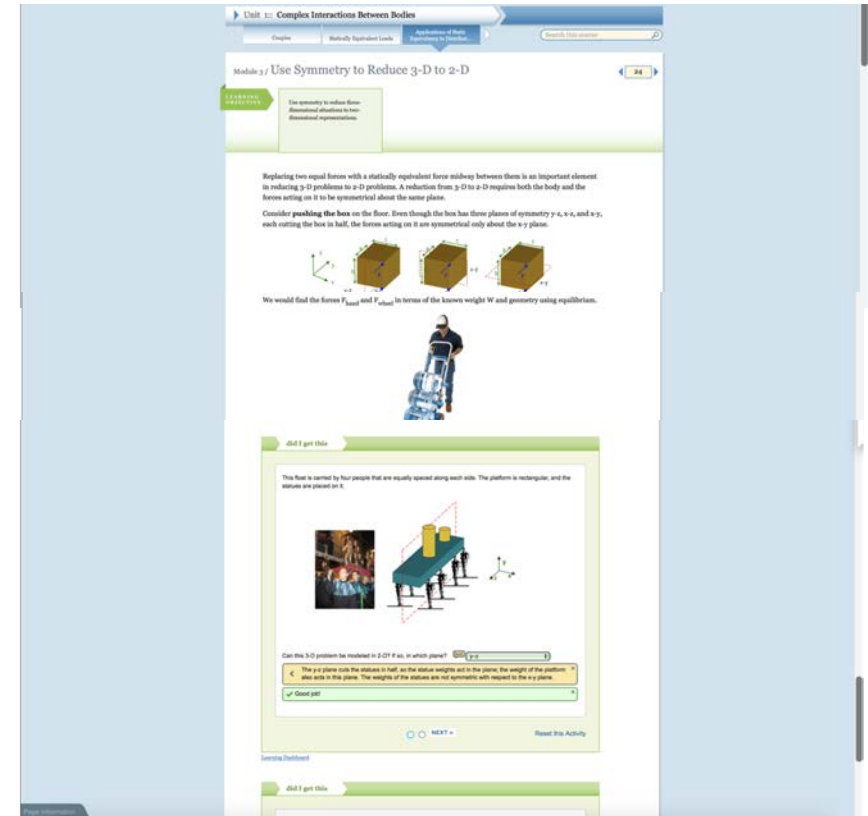
where $0 \leq k \leq n - 2$

As already mentioned, the decomposition into transpositions is not unique. In fact, not even the number of transpositions used is unique. However, there is still an invariant.

Even permutation

(definition) A permutation is even if it can be written as the product of an even number of transpositions, and odd if it can be written as the product of an odd number of transpositions.

Sequenced, Integrated Learning Environments



Unit 3: Complex Interactions Between Bodies

Chapter: Mutually Dependent Levels

Module 3 / Use Symmetry to Reduce 3-D to 2-D

The geometry to reduce from 3-dimensional situations to 2-dimensional representations.

Replacing two equal forces with a statically equivalent force midway between them is an important element in reducing 3-D problems to 2-D problems. A reduction from 3-D to 2-D requires both the body and the forces acting on it to be symmetrical about the same plane.

Consider pushing the box on the floor. Even though the box has three planes of symmetry $y-x$, $x-z$, and $x-y$, each cutting the box in half, the forces acting on it are symmetrical only about the $x-y$ plane.

We would find the forces $F_{x,y}$ and $F_{x,z}$ in terms of the known weight W and geometry using equilibrium.

did I get this

This floor is carried by four people that are equally spaced along each side. The platform is rectangular, and the statues are placed on it.

Can this 3-D problem be reduced to 2-D? If so, in which plane?

The $x-y$ plane cuts the statues in half, so the statue weights act in the plane. The weight of the platform also acts in the plane. The weights of the statues are not symmetrical with respect to the $x-y$ plane.

Good job!

Next

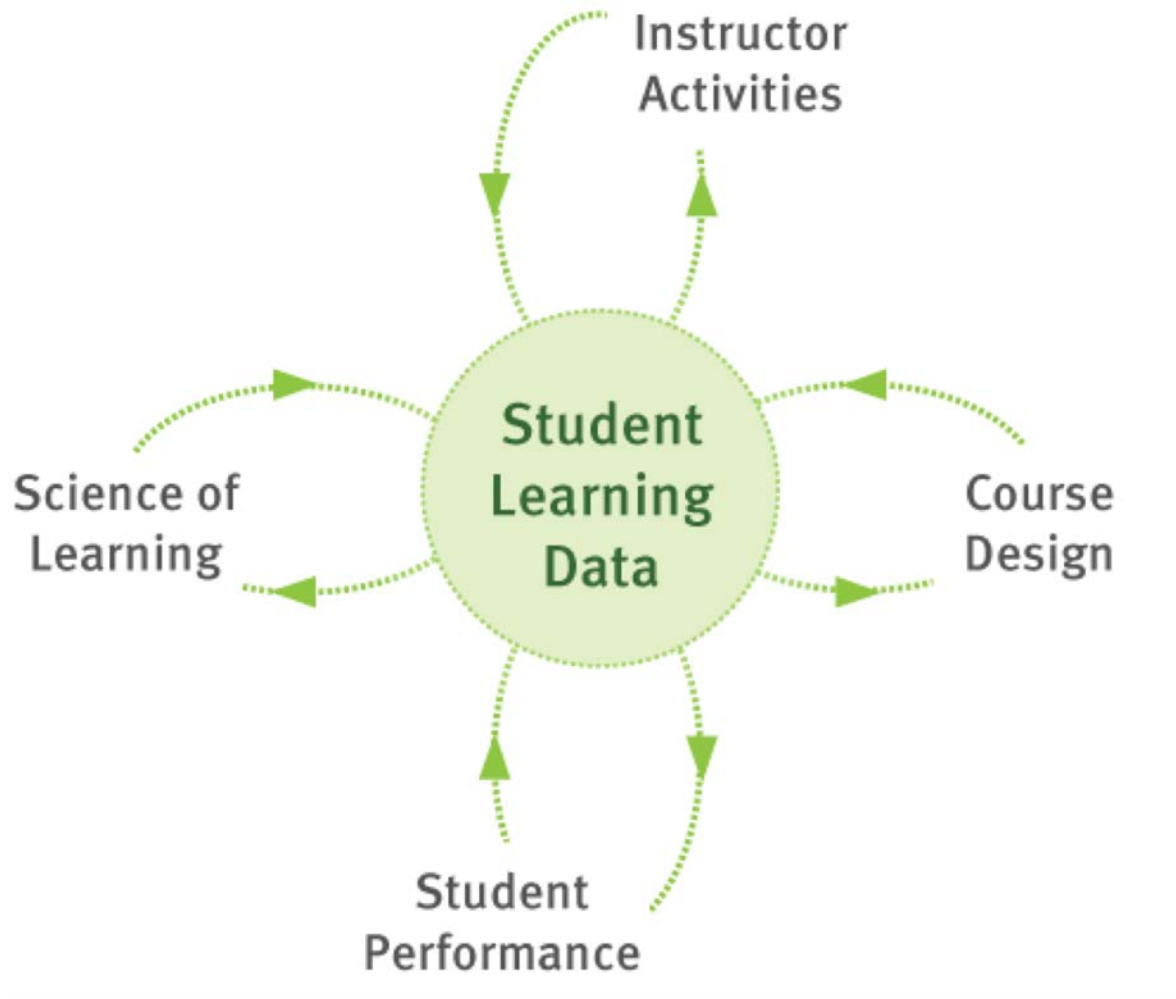
Reset this Activity

Settings/Feedback

did I get this



Data drives powerful **Feedback Loops**



Module 2

Examining Relationships



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. [Show Sub-Learning Objectives]



Produce a two-way table, and interpret the information stored in it about the association between two cat. variables by comparing conditional percents. [Show Sub-Learning Objectives]

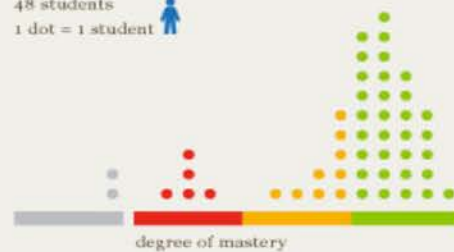


Classify a data analysis situation (involving two variables) according to the "role type classification," and state the appropriate display and/or numerical measures that should be used in order to summarize the data. [Hide Sub-Learning Objectives]



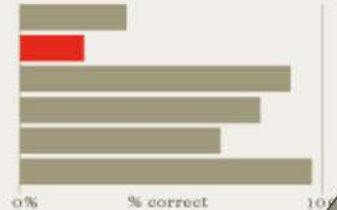
Predicted Mastery by Student

48 students
1 dot = 1 student



Class Accuracy by Sub-Learning Objective

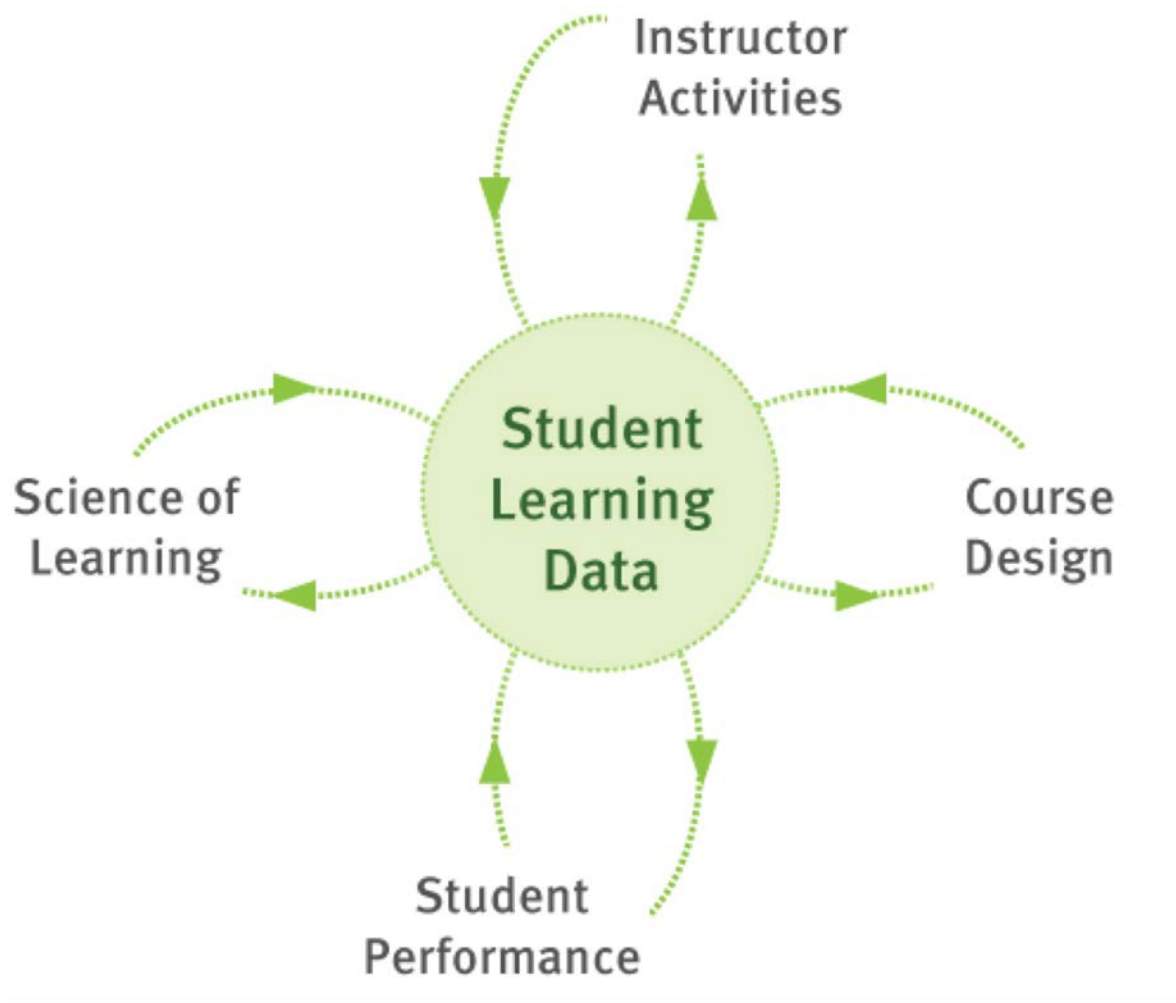
- Identify relevant variables
- Classify variable's role**
- Classify variable's type
- Identify correct case
- State appropriate display
- State appropriate numerical ...



Module-Level Reports



Feedback loops for **continuous improvement**



Data Driven Course Improvement



HOME
COURSES
LOG OUT

Integrated Development Environment with Analytics
IDEA

IDEA provides a tight connection between student performance and course components to help course developers and instructors to...

- validate course design before actual use with students
- leverage student learning data to discover barriers to learning
- analyze learning curves, modify skill models to target areas for improvement

Learning Model Design
Performance Profile

COURSES

Biology		
BioChemistry		
Computing for Non-Majors		
Statistics		

Footer: creative commons/copyright 2016, funding, a variety of logos, contact, how to, etc

Learning Model Performance

discrete_math_primer-1.0

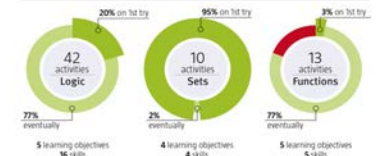
Top 5 concerns for student learning?

Skill Label	learning curve: is the model working?	% correct: first try vs eventually?	correlation between practice to exam performance?
1. large_formulae	still high/students not performing well	20% # activities	strong positive
2. calculate_functions_SKILL	still high/students not performing well	10% # activities	positive
3. large_formulae	no learning/add more practice; check skills	60% # activities	negative
4. express_numbers_SKILL	low to flat/too easy	98% # activities	not enough data
5. _SKILL	low to flat/too easy	100% # activities	not enough data

Are students using practice? % of Students doing practice activities



Are students successful on practice? [DOERS] % Correct on first try vs eventually



Is your model indicate learning? Learning curves per skill

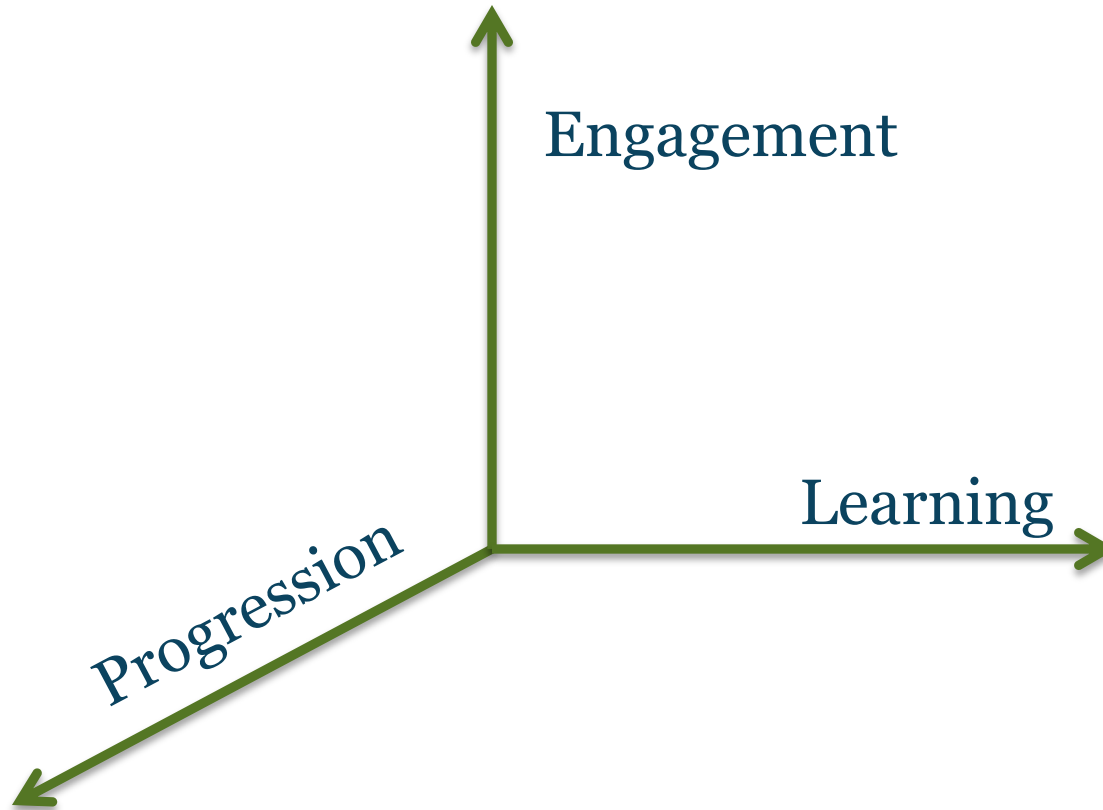
large_formulae	still high/students not performing well
express_numbers_SKILL	still high/students not performing well
large_formulae	no learning/add more practice; check skills
calculate_functions_SKILL	low to flat/too easy

How does practice affect performance on high stakes exams? Correlation between practice and test

Logic	strong positive
Sets	positive
Functions	negative



What do we mean by Analytics? Models?



Credit: mike.sharkey@phoenix.com



Evaluating New Approaches



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"A brilliant teacher, Christensen brings clarity to a muddled and chaotic world of education." -JIM COLLINS, bestselling author of *Good to Great*

Disrupting Class

How Disruptive Innovation Will Change the Way the World Learns



Clay
BESTSELLER
Michael

The Year of the MOOC

By LAURA PAPPANO NOV. 2, 2012

OPINION

How big data is disrupting education

Disruption by data: Education

Technology



AI's huge potential to transform education

December 5, 2018 by Thierry Karsenti, University of Montreal



Credit: CC0 Public Domain

tor In

nal

Future With Only 10 Universities

by Andrew Watters on 15 Oct 2013



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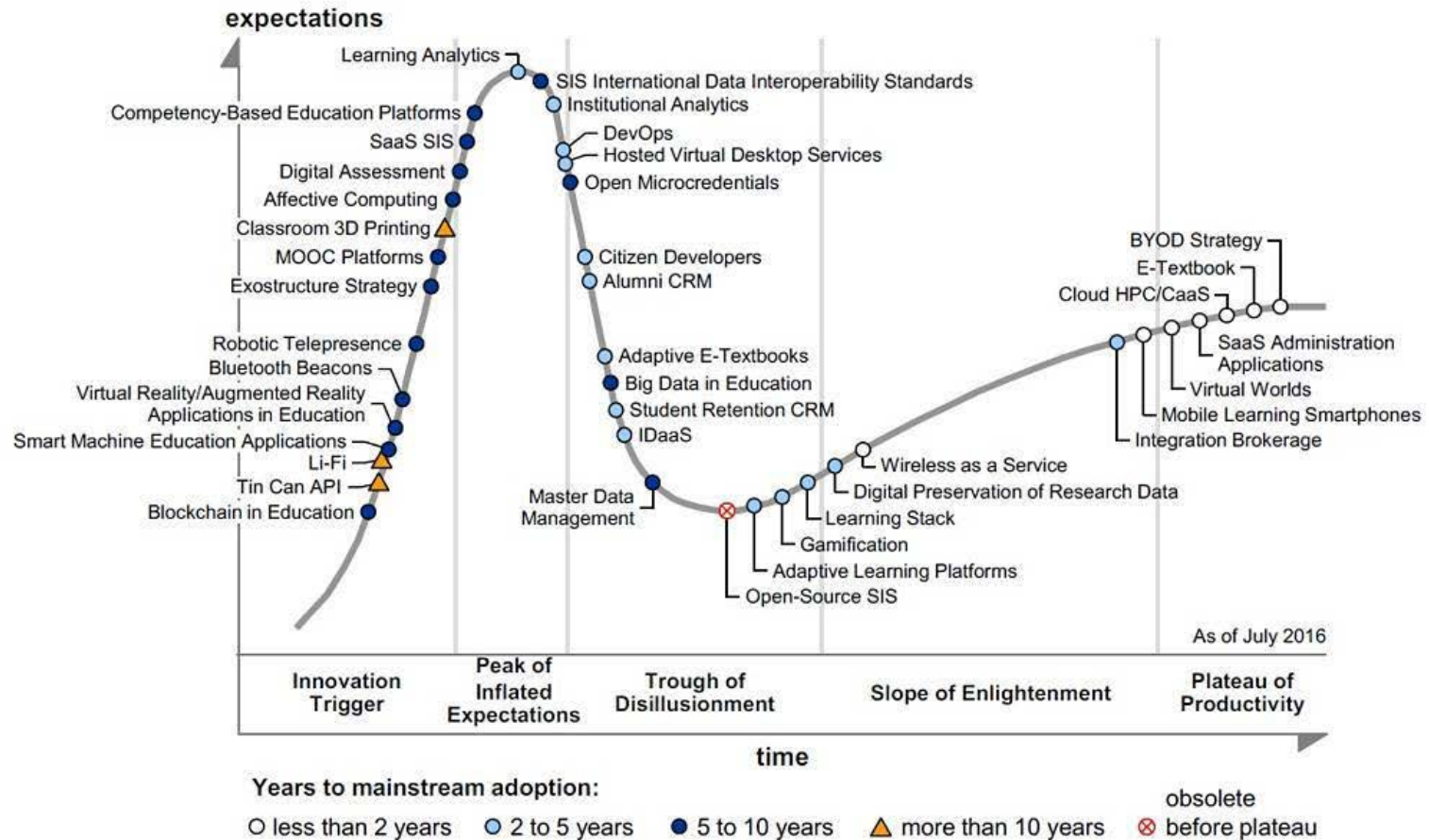
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Don't Believe the Hype



Hype Cycle – who's to blame?

Figure 1. Hype Cycle for Education, 2016



Evidence



Created by Dinosoft Labs
from Noun Project



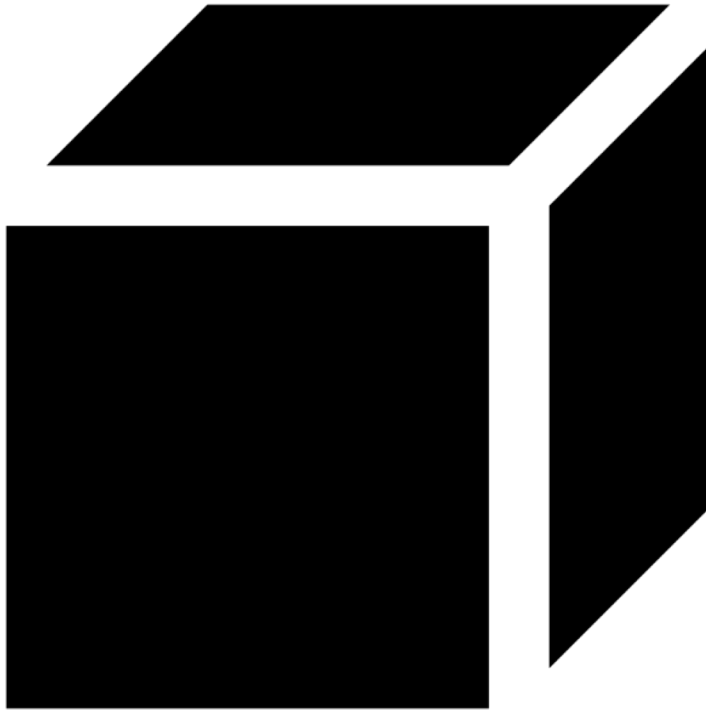
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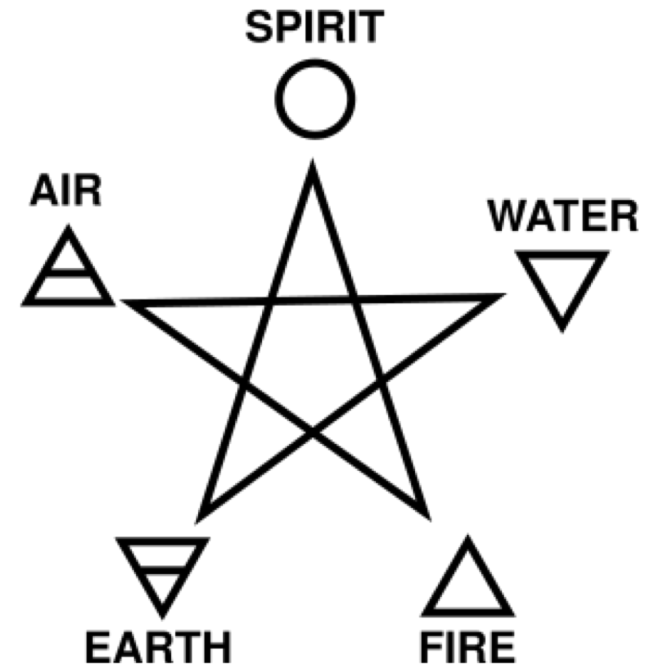
Periodic Table of the Elements																18 VIIIA He																			
1 IA H Hydrogen 1.008												2 IIA He Helium 4.003																							
3 Li Lithium 6.941		4 Be Beryllium 9.012												5 B Boron 10.811		6 C Carbon 12.011		7 N Nitrogen 14.007		8 O Oxygen 15.999		9 F Fluorine 18.998		10 Ne Neon 20.180											
11 Na Sodium 22.990		12 Mg Magnesium 24.305		3 IIIB Sc Scandium 44.956		4 IVB Ti Titanium 47.88		5 VB V Vanadium 50.942		6 VIB Cr Chromium 51.996		7 VIIB Mn Manganese 54.938		8 VIII Fe Iron 55.933		9 VIII Co Cobalt 58.933		10 VIII Ni Nickel 58.693		11 IB Cu Copper 63.546		12 IIB Zn Zinc 65.39		13 Al Aluminum 26.982		14 Si Silicon 28.086		15 P Phosphorus 30.974		16 S Sulfur 32.06		17 Cl Chlorine 35.453		18 Ar Argon 39.948	
19 K Potassium 39.098		20 Ca Calcium 40.078		21 Sc Scandium 44.956		22 Ti Titanium 47.88		23 V Vanadium 50.942		24 Cr Chromium 51.996		25 Mn Manganese 54.938		26 Fe Iron 55.933		27 Co Cobalt 58.933		28 Ni Nickel 58.693		29 Cu Copper 63.546		30 Zn Zinc 65.39		31 Ga Gallium 69.723		32 Ge Germanium 72.61		33 As Arsenic 74.922		34 Se Selenium 78.09		35 Br Bromine 79.904		36 Kr Krypton 83.80	
37 Rb Rubidium 84.468		38 Sr Strontium 87.62		39 Y Yttrium 88.906		40 Zr Zirconium 91.224		41 Nb Niobium 92.906		42 Mo Molybdenum 95.94		43 Tc Technetium 98.907		44 Ru Ruthenium 101.07		45 Rh Rhodium 102.906		46 Pd Palladium 106.42		47 Ag Silver 107.868		48 Cd Cadmium 112.411		49 In Indium 114.818		50 Sn Tin 118.71		51 Sb Antimony 121.760		52 Te Tellurium 127.6		53 I Iodine 126.905		54 Xe Xenon 131.29	
55 Cs Cesium 132.905		56 Ba Barium 137.327		57-71 Lanthanide Series		72 Hf Hafnium 178.49		73 Ta Tantalum 180.948		74 W Tungsten 183.85		75 Re Rhenium 186.207		76 Os Osmium 190.23		77 Ir Iridium 192.22		78 Pt Platinum 195.08		79 Au Gold 196.967		80 Hg Mercury 200.59		81 Tl Thallium 204.383		82 Pb Lead 207.2		83 Bi Bismuth 208.980		84 Po Polonium [209]		85 At Astatine 210		86 Rn Radon 222.018	
87 Fr Francium 223.02		88 Ra Radium 226.025		89-103 Actinide Series		104 Rf Rutherfordium [261]		105 Db Dubnium [262]		106 Sg Seaborgium [266]		107 Bh Bohrium [264]		108 Hs Hassium [265]		109 Mt Meitnerium [266]		110 Ds Darmstadtium [271]		111 Rg Roentgenium [272]		112 Cn Copernicium [277]		113 Nh Nihonium [284]		114 Fl Flerovium [289]		115 Uu Ununpentium [294]		116 Lv Livermorium [293]		117 Uus Ununseptium [294]		118 Uuo Ununoctium [294]	
57 La Lanthanum 138.906		58 Ce Cerium 140.115		59 Pr Praseodymium 140.908		60 Nd Neodymium 144.24		61 Pm Promethium 144.913		62 Sm Samarium 150.36		63 Eu Europium 151.966		64 Gd Gadolinium 157.25		65 Tb Terbium 158.925		66 Dy Dysprosium 162.50		67 Ho Holmium 164.930		68 Er Erbium 167.26		69 Tm Thulium 168.934		70 Yb Ytterbium 173.04		71 Lu Lutetium 174.967							
89 Ac Actinium 227.028		90 Th Thorium 232.038		91 Pa Protactinium 231.036		92 U Uranium 238.029		93 Np Neptunium 237.048		94 Pu Plutonium 244.064		95 Am Americium 243.061		96 Cm Curium 247.070		97 Bk Berkelium 247.070		98 Cf Californium 251.080		99 Es Einsteinium [252]		100 Fm Fermium [257]		101 Md Mendelevium 258.1		102 No Nobelium 259.101		103 Lr Lawrencium [262]							

© 2013 Todd Hollens

No Black Boxes



Created by Anna Sophie
from Noun Project



Instrumented



- Data Collection
- NOT Click Stream
- Learner Interactions
- Semantic Context
- Implies Design




Ethical Data Collection and Use

Asilomar Convention

<http://asilomar-highered.info>



 **Open Learning Initiative**
Transforming higher education through the science of learning.

[My Courses](#)
[Help](#)
[Announcements](#)

Hello, Norman

Carnegie Mellon University
Open Learning Initiative
Online Consent Form

I agree to participate in the on-line course research conducted by Norman Bier and his colleagues under the supervision of Norman Bier. I understand that the proposed research has been reviewed by the University's Institutional Review Board. I understand that my participation is completely voluntary, and I will not receive course credit or any other compensation from Carnegie Mellon for my participation in this research. I understand that I have the right to terminate my participation at any time I wish without penalty by selecting "opt out from research" on "my OLI home" page.

Purpose of the Study: I know that the researchers are studying how students learn in an online educational environment and that the study is directed at improving the course material, not judging my behaviors. As a result of this research, the researchers will produce design recommendations to improve future versions of the courses. I understand that my interactions with the on-line course will be logged in a data file and that these logs and the scores that I receive on exams will be used as data for this study. The only difference between agreeing to participate in the study and not agreeing to participate in the study is that if I agree to participate, my log file will be retained as data for this study, if I do not agree, my log file will not be retained.

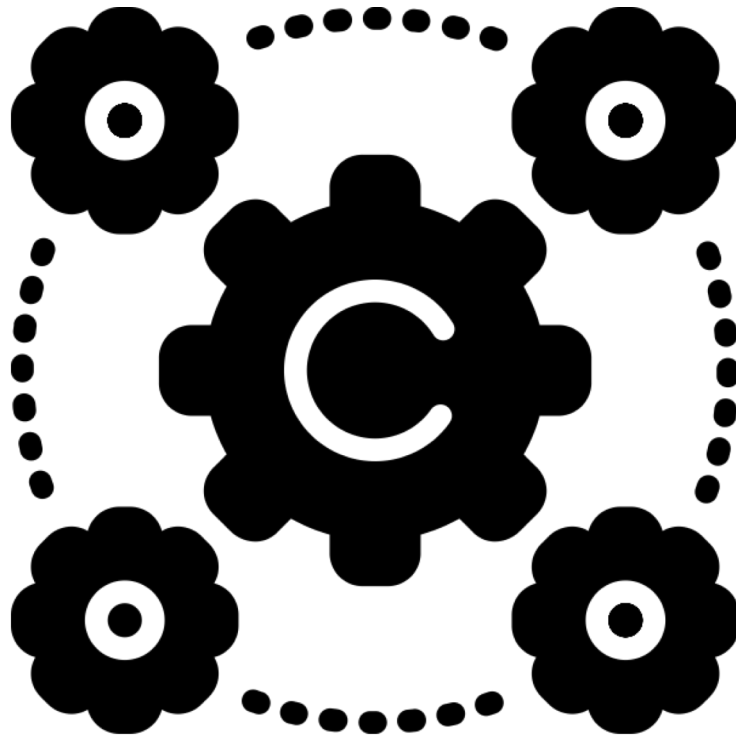
Privacy: I understand that the following procedure will be used to maintain my anonymity in analysis and publication / presentation of any results. Each participant will be assigned an ID; names will not be logged with the study data. The researchers will save the data using this participant ID. Only registered OLI researchers will have access to the logged data for analysis purposes. The servers containing the log files are in locked secure room. No other researchers will have access to these files.

I understand the nature of this Study. I am at least 18 years of age and agree to participate. I can view of copy of this consent form at any time by selecting the "Research Consent Form" link on the "my OLI home" page. I give Mr. Bier and his colleagues permission to present this work in written and/or oral form for teaching or presentations to advance the knowledge of science and/or academia, without further permission from me provided that my image or identity is not disclosed.

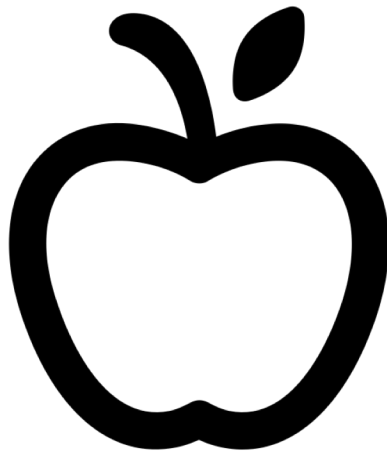
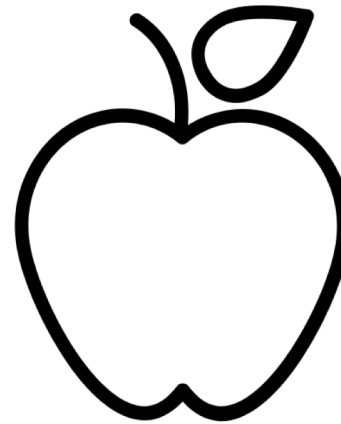
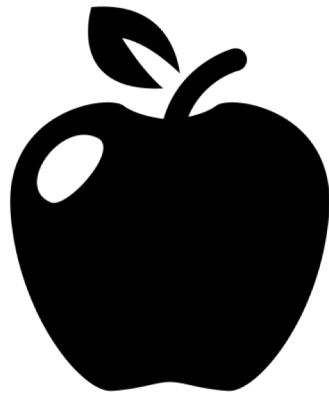
☐ I Agree ☒ I Disagree



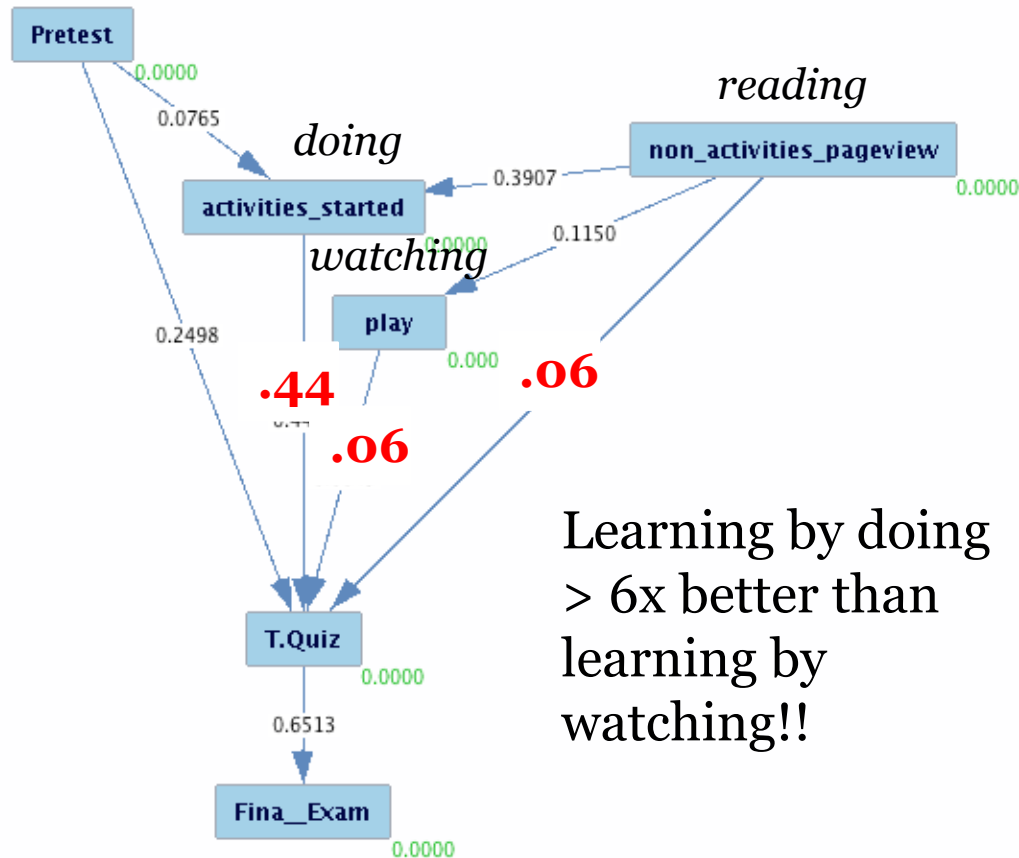
Interoperability & Standards Complaint



Comparable



What student choices associate with the most learning?



Learning by doing
> 6x better than
learning by
watching!!

Watching lecture video

Psychology

- Brain & Behavior
- Sensation & Perception
- Learning & Memory
- Cognition & Language

Reading web pages

Doing online activities with hints & feedback

Complete the table below by dragging each of the major factors of personality based on the Five-Factor (Big Five) Model of Personality to their proper location, between the corresponding traits of both extremes. Note that each factor represents a dimension, or range, between two extremes.

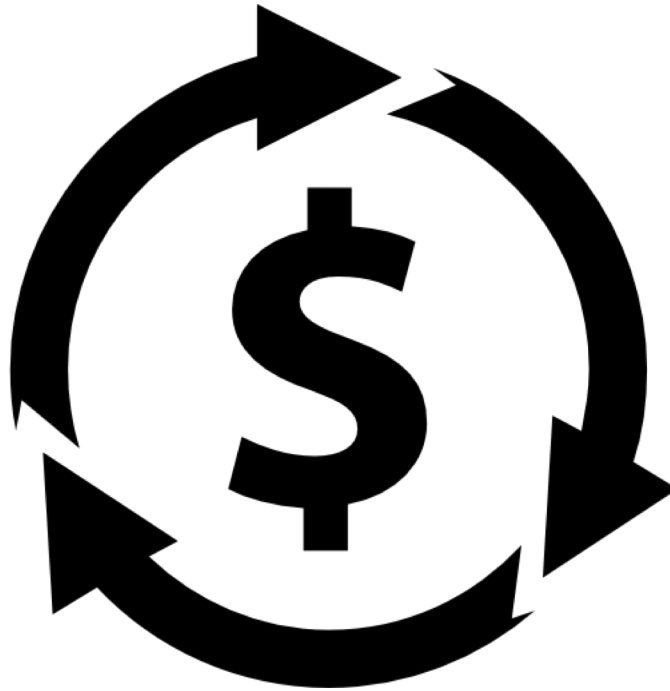
Low Extreme Traits	Factor	High Extreme Traits
Calm, even-tempered, unemotional, hearty		Worrying, temperamental, emotional, vulnerable
Reserved, lower, quiet		Affectionate, gregarious, talkative
Down-to-earth, conventional, uncreative, prefer routine		Imaginative, original, creative, prefer variety
Antagonistic, ruthless, suspicious		Sympathetic, softhearted, trusting
Lazy, aimless, quitting		Hardworking, ambitious, persevering

Agreeableness | Conscientiousness | Extraversion | Openness to experience | Neuroticism

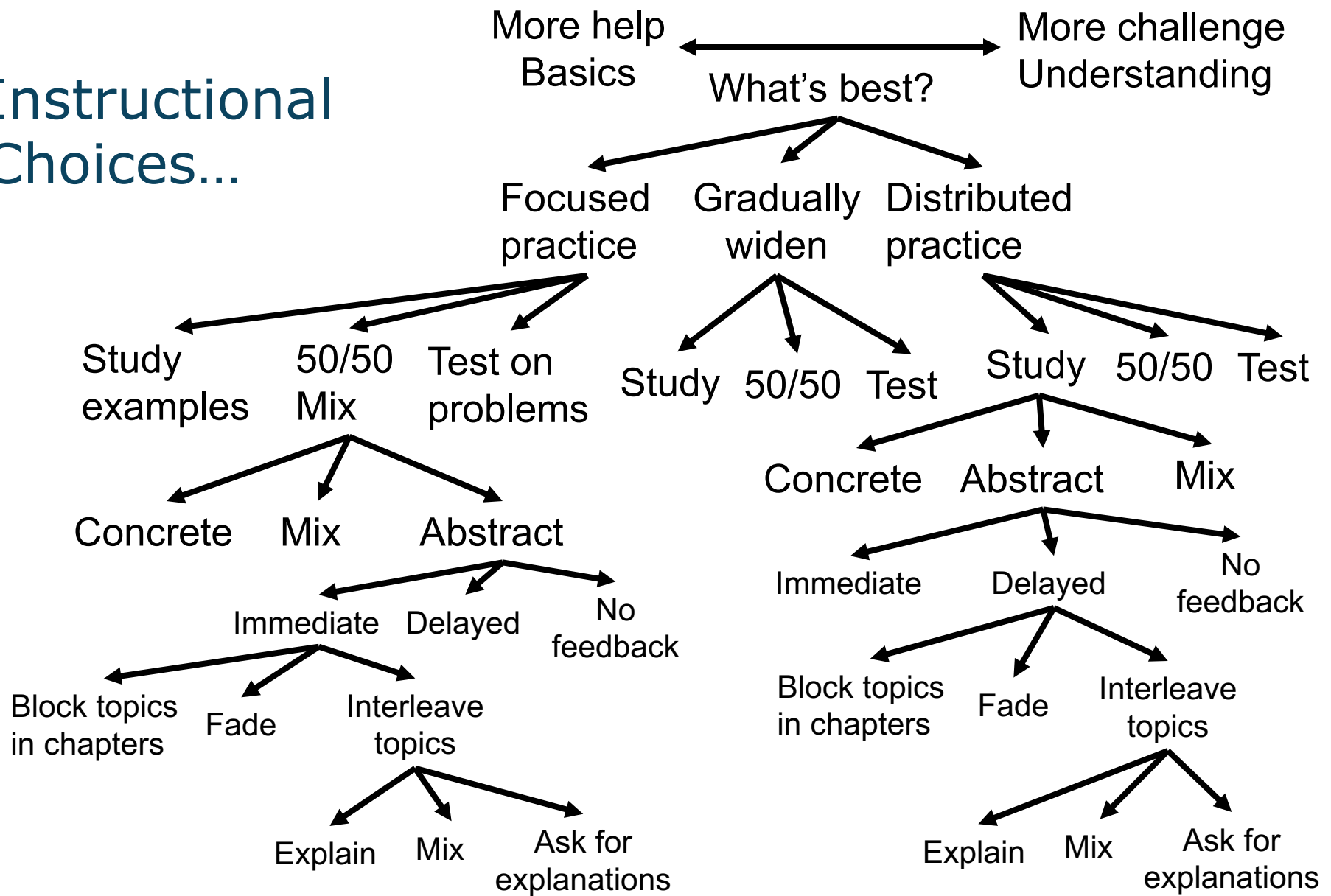
Koedinger, Kim, Jia, McLaughlin, & Bier (2015). Learning is not a spectator sport: Doing is better than watching for learning from a MOOC. In *Proceedings of the Second ACM Conference on Learning at Scale*.



Sustainable



Instructional Choices...

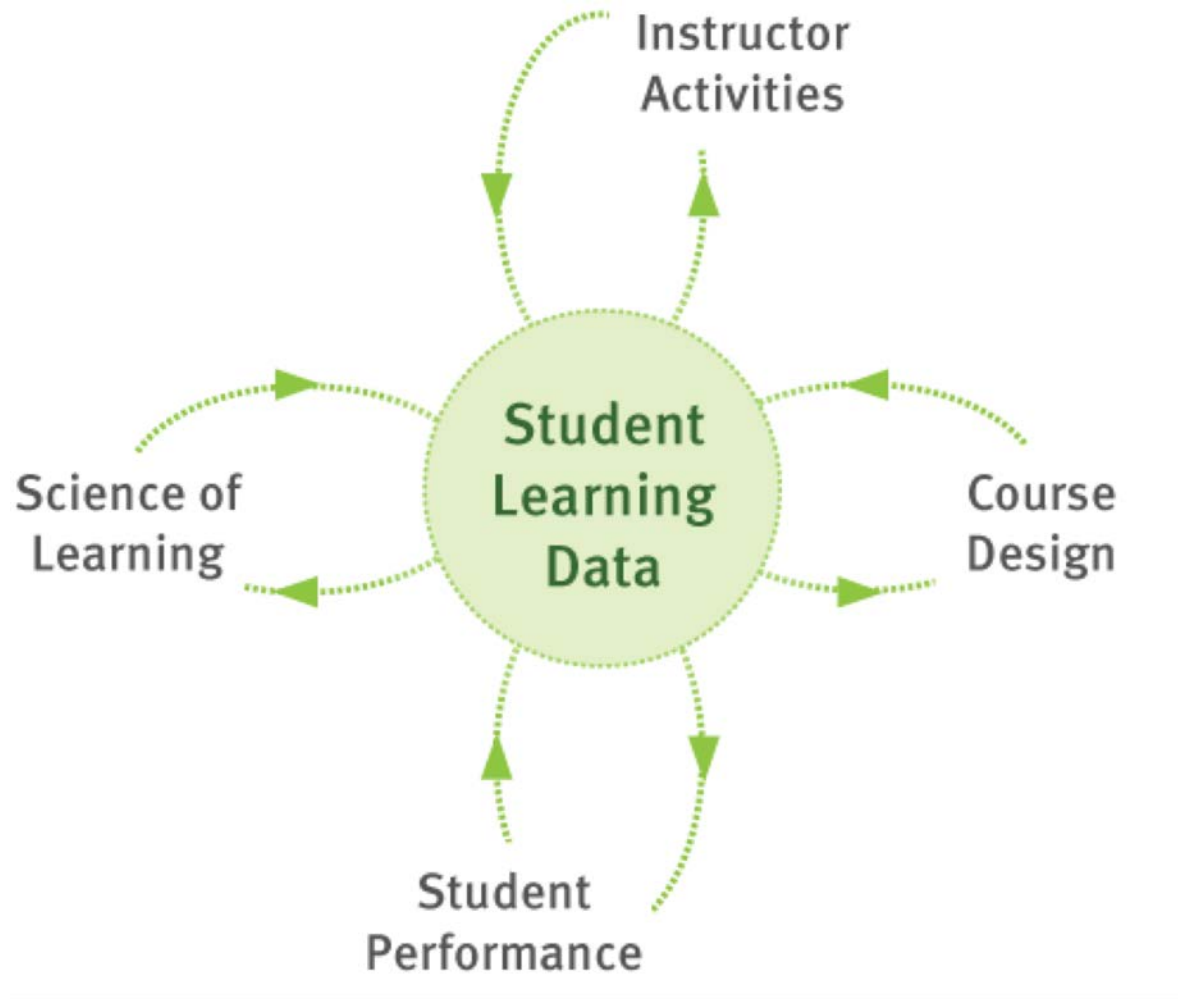


Many other choices: animations vs. diagrams vs. not, audio vs. text vs. both, ...

Some tools...and how they measure up



Data drives powerful **Feedback Loops**



Module 2

Examining Relationships



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. [Show Sub-Learning Objectives]



Produce a two-way table, and interpret the information stored in it about the association between two cat. variables by comparing conditional percents. [Show Sub-Learning Objectives]

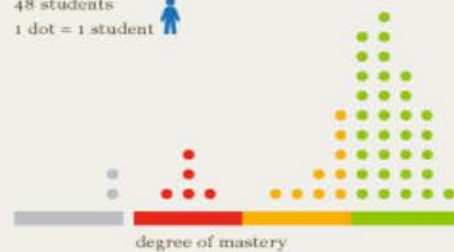


Classify a data analysis situation (involving two variables) according to the "role type classification," and state the appropriate display and/or numerical measures that should be used in order to summarize the data. [Hide Sub-Learning Objectives]



Predicted Mastery by Student

48 students
1 dot = 1 student



Class Accuracy by Sub-Learning Objective

Identify relevant variables

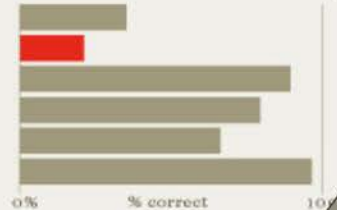
Classify variable's role

Classify variable's type

Identify correct case

State appropriate display

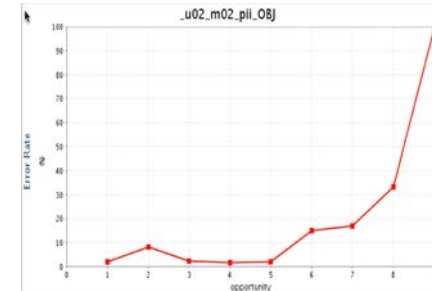
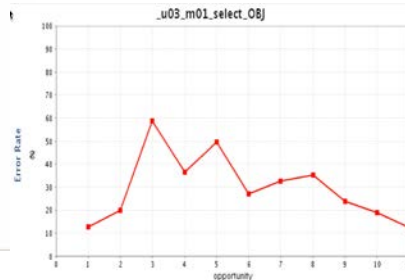
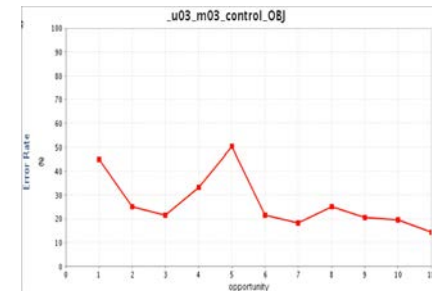
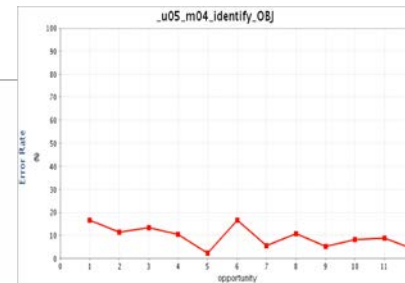
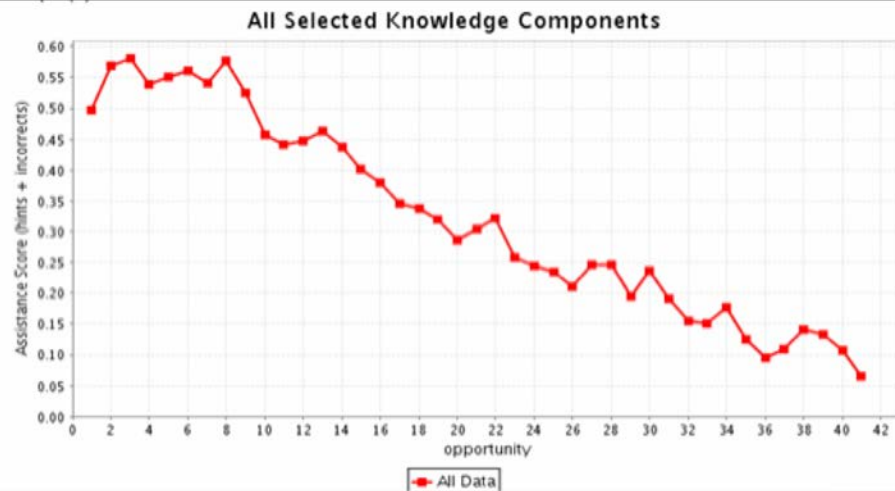
State appropriate numerical ...



Module-Level Reports



Model Analytics (Learning Curve Analysis)



LearnLab
DataShop



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Carnegie Mellon University

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Design Analytics

E-Learning Design Principles

Objectives

Organizations

Pages

Assessments

Logout

Apply thinking skills principles

Focus on job-specific thinking skills

Design whole-task learning environments

Make thinking processes explicit

Base lessons on cognitive task analysis

Reword

Remove

Pages

1

E-Learning to Build Problem Solving Skills

Skills

4

Add Existing Skill

Create New Skill

1	0	2	✓	Focus on job-specific thinking skills																
1	3	3	✓	Design whole-task learning environments																
1	0	6	✓	Make thinking processes explicit																
1	0	2	✓	Base lessons on cognitive task analysis																

Identify the characteristics of a good experiment

1 Page

1 Skill

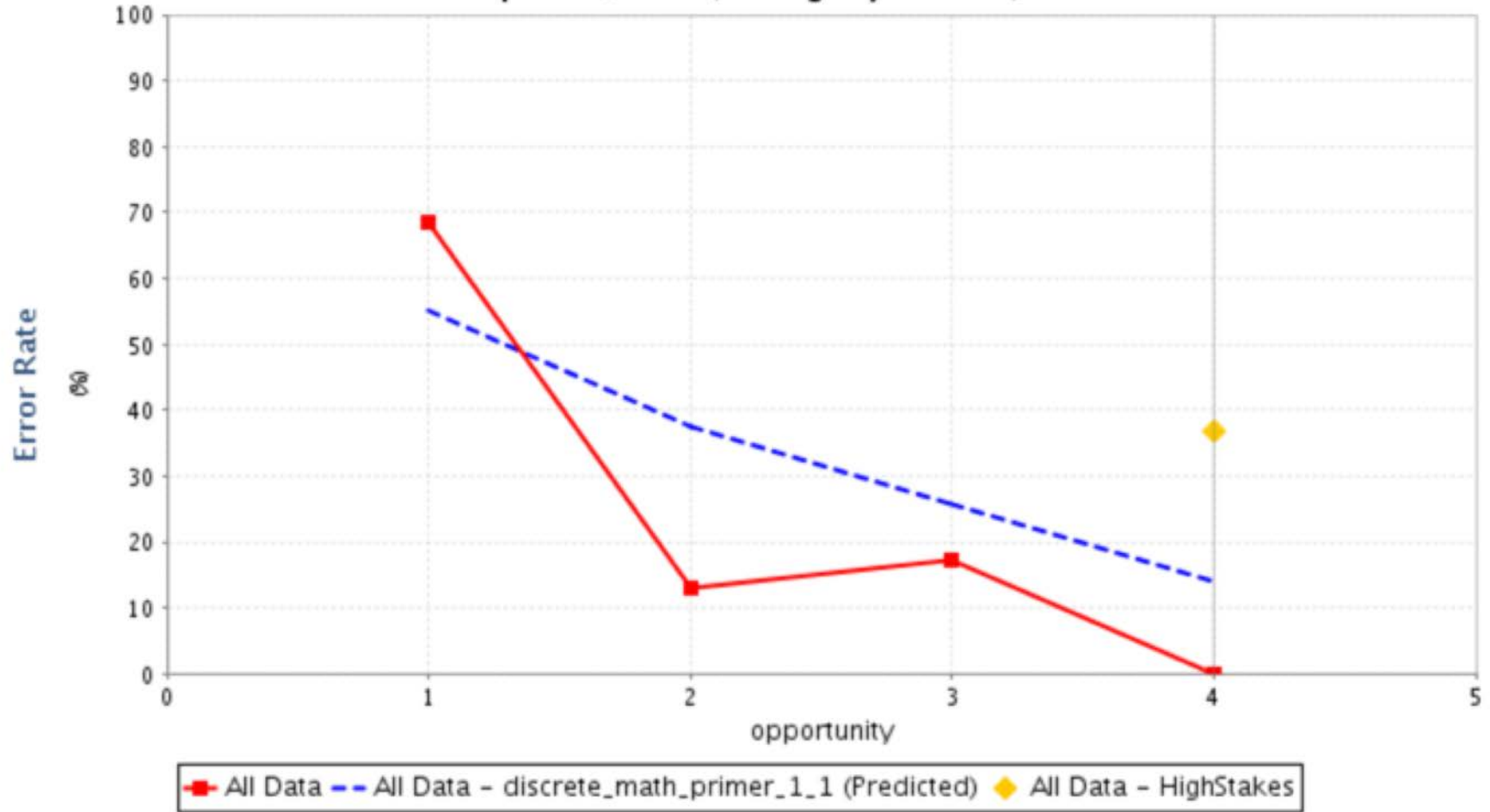
7

1

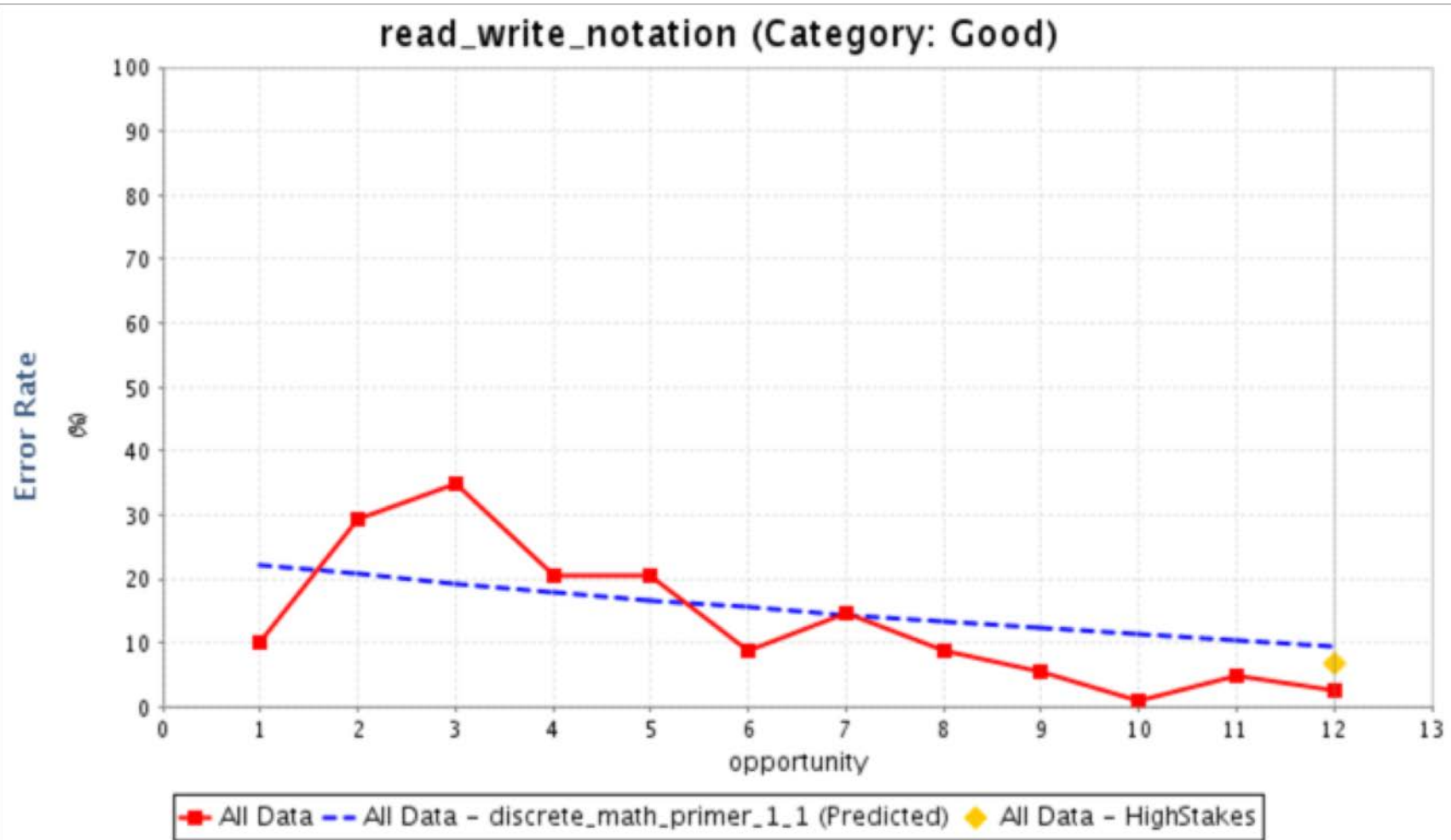
✓

Discontinuity Analysis (Datashop)

express_lists (Category: Good)



Discontinuity Analysis (Datashop)



How to make data actionable?



[HOME](#)
[COURSES](#)
[LOG OUT](#)

Integrated Development Environment with Analytics

IDEA

IDEA provides a tight connection between student performance and course components to help course developers and instructors to...

- validate course design before actual use with students
- leverage student learning data to discover barriers to learning
- analyze learning curves, modify skill models to target areas for improvement

Learning Model Design

Performance Profile

COURSES

<input type="radio"/> Biology		
<input type="radio"/> BioChemistry		
<input type="radio"/> Computing for Non-Majors		
<input type="radio"/> Statistics		

Footer: creative commons/copyright 2016, funding, a variety of logos, contact, how to, etc

Learning Model Performance

discrete_math_primer-1.0

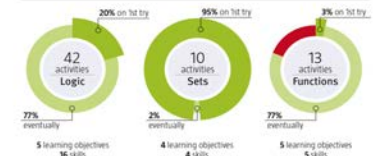
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Skill Label	learning curve: is the model working?	% correct: first try vs eventually?	correlation between practice to exam performance?
1. large_formulae	still high/students not performing well	20% # activities	strong positive
2. calculate_functions_SKILL	still high/students not performing well	10% # activities	positive
3. large_formulae	no learning/add more practice; check skills	60% # activities	negative
4. express_numbers_SKILL	low to flat/too easy	98% # activities	not enough data
5. _SKILL	low to flat/too easy	100% # activities	not enough data

Are students using practice? % of Students doing practice activities



Are students successful on practice? [DOERS] % Correct on first try vs eventually



Is your model indicate learning? Learning curves per skill

large_formulae	still high/students not performing well
express_numbers_SKILL	still high/students not performing well
large_formulae	no learning/add more practice; check skills
calculate_functions_SKILL	low to flat/too easy

How does practice affect performance on high stakes exams? Correlation between practice and test

Logic	strong positive
Sets	positive
Functions	negative



(some) Rules for Evaluating

- No Hype
- Science – iterative and steady
- Instrumented
- Semantic Context
- Interoperable and Standards Compliant
- Integrated Into Instructional Context
- Comparable
- No Black Boxes -- Open
- Sustainable
- Ethical Data Use



Thank You!



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