Learning Forge

Learning Engineering: What we know, What we can do

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Founder

February 1, 2023

Learning engineering helps increase the odds of learning success

- A lot is known about learning and motivation from careful work over decades
- “Learning engineering” is the application of insights from learning sciences to real-world problems at scale
- When applied well, it can make a difference
- So let’s do that!

Insights we have from learning science

- An important model for human expertise
- Equally important insights about motivation
- Resulting guidelines for instruction

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We know a lot about how cognitive expertise works

Audio & visual inputs

Working Memory	Long-Term Memory
Short retention	Long retention
Audio + video = benefits	Auto-connect to WM
Verbal/conscious Only 3-5 things at once (prone to too much cognitive load)	Non-verbal/Non-conscious
Slow processing	Highly parallel, rapid
Error-prone	Error-free (with proper training)
Highly flexible - can generate new insights/knowledge	Rigid – decisions and tasks must “fit”

Much expertise is no longer verbally accessible to experts

- Less than 30% is verbally accessible
- Explains why learners find much "expert-created" learning/training does not prepare them for real-world work
- Techniques like cognitive task analysis (CTA) get at more of expertise
- Rarely used in learning environments

We also know quite a lot about motivation

Motivation Barriers		Motivation Actions		Learning/Results
• Value • Self-efficacy • Attribution • Negative emotions	→	• Starting • Persisting • Mental effort	→	• Practice results • Test results • Fluency/ease • Work results

Source: Clark, R. E., & Saxberg, B. (2018). Engineering motivation using the belief-expectancy-control framework. Interdisciplinary Education and Psychology, 2(1), 1-26

Motivation issues benefit from different treatments

Problems with:	E.g.:	Approaches to resolve
Value	*"I don't see the point"*	Help learner find value Let learner use their existing expertise Make the activity itself be enjoyable
Self-efficacy	*"I can't do this"*	Show they have done things like this before Show stories from others like them who've mastered this before
Attribution	*"<Something> is in my way"*	Problem-solve around the issue (Space? Time? Materials not working? Etc.) Show stories from others like them with this issue who've found a solution
Emotional state	*"I'm <angry/depressed/scared/grieving>"*	Wide array of possible solutions, from structured conversation techniques through more professional help

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Source: Clark, R. E., & Saxberg, B. (2018). Engineering motivation using the belief-expectancy-control framework. Interdisciplinary Education and Psychology, 2(1), 1-26

Impact of applying these insights at scale

- Deeper understanding of expertise should help us prepare learners
- Improve instructional method choices
- Improve overall outcomes for learners
- Improve tools for teachers/trainers

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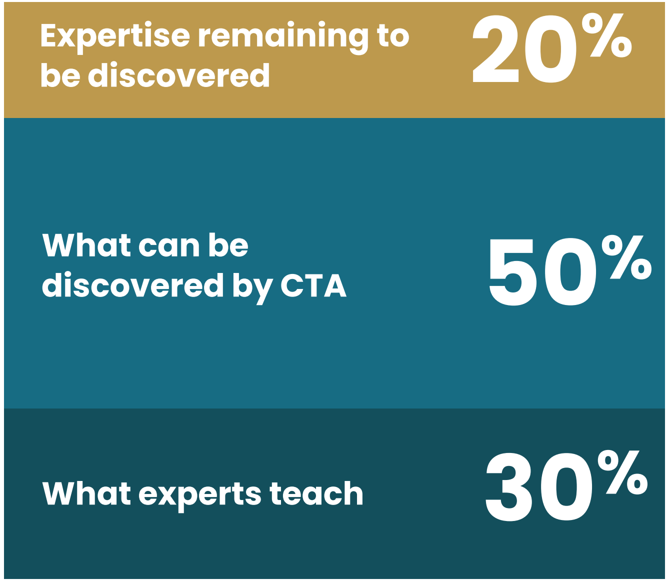
It requires work to unpack more of expertise: Cognitive Task Analysis (CTA)

Expert performance **100%**



CTA is based on structured interviews with top experts identified with data, not opinion.

Interviews identify key decisions and tasks and then the steps behind these.

These interviews are refined to a “gold standard” and used to drive instruction.

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CTA separates tools, knowledge, and context
Paralegal example

Tool skills	Prior knowledge	Context analysis

• Critical thinking skills
• Organizational skills
    • General organizational skills
    • Litigation
    • Corporate
• General communication skills
• Legal research skills
• Legal writing skills
    • Litigation
    • Corporate
    • Criminal
• Computer skills
	• History of Jurisprudence; overview of the US Constitution; the US court system
	• Contract Law
	• Tort Law
	• Property Law
	• Civil Litigation
	• Criminal Law
		• Clear layout of work setting and surrounding activities to trigger paralegal skills in the right sequence
		• Sequences of tasks, and steps within tasks, for different contexts

CTA identifies expertise missing in typical programs

Paralegal example:

Only 4 of 13 critical paralegal tasks typically taught

CTA Expert Identified Activities	Modules in Paralegal Curriculum
Intake interview	Unit 1: Justin King Case Unit 2: Pre-Complaint Investigation
Identify conflicts	*NOT TAUGHT*
Determine & comply pre-litigation notices or demands	*NOT TAUGHT*
Draft & file a complaint	Unit 3: Drafting the Complaint Unit 4: Pre-Answer Investigation Unit 5: Pre-Complaint Investigation
Motion/Pleadings	*NOT TAUGHT*
Discovery	Unit 6: Discovery I Unit 7: Discovery II
Pre-trial	Unit 8: Pre-trial Motions & Settlements Unit 9: Getting Ready for Trial
Trial	*NOT TAUGHT*
Post-trial	*NOT TAUGHT*
Settlement	*NOT TAUGHT*
Appellate filings & hearings	*NOT TAUGHT*
Technology Tools: e-Discovery	*NOT TAUGHT*
Technology Tools: Litigation Tools	*NOT TAUGHT*

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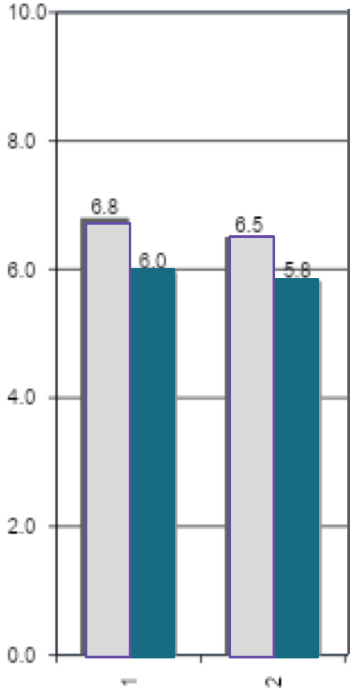
When training parallels what experts actually do, it matters
Example - Impact of CTA on college career placement work: Before CTA-based training. . .

Mean Placements per CSA by Month

Treatment Group

Control Group



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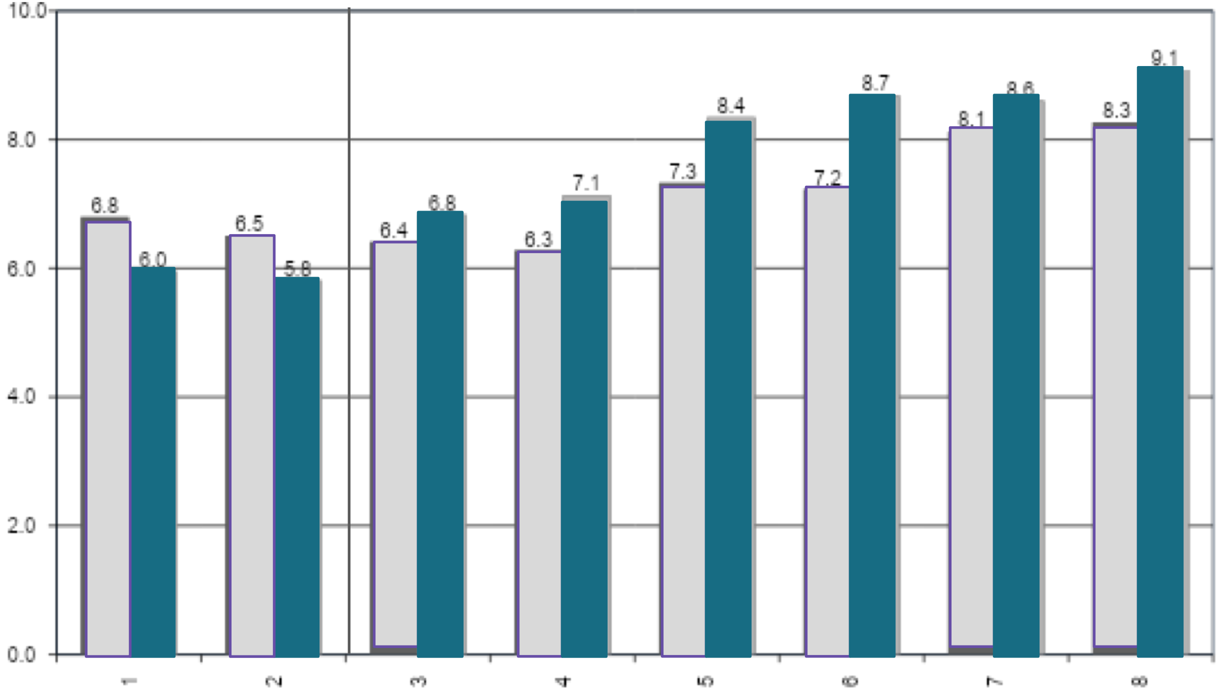

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Research offers specific guidance to lower cognitive load

Principle	Description	Effect size (s.d. units)
Multimedia	Use relevant graphics and text to communicate content	1.4
Contiguity	Integrate the text nearby the graphics on the screen – avoid covering or separating integrated information	1.1
Coherence	Avoid irrelevant graphics, stories, videos, media, and lengthy text	0.9
Modality	Include audio narration where possible to explain graphic presentation	0.8
Redundancy	Do not present words as both on-screen text and narration when graphics are present	0.9
Personalization	Script audio in a conversational style using first and second person	0.8
Segmenting	Break content down into small topic chunks that can be accessed at the learner's preferred rate	0.8
Pre-training	Teach important concepts and facts prior to procedures or processes	0.8
Etc.	Worked examples, self-explanation questions, varied-context examples and comparisons, etc.	??

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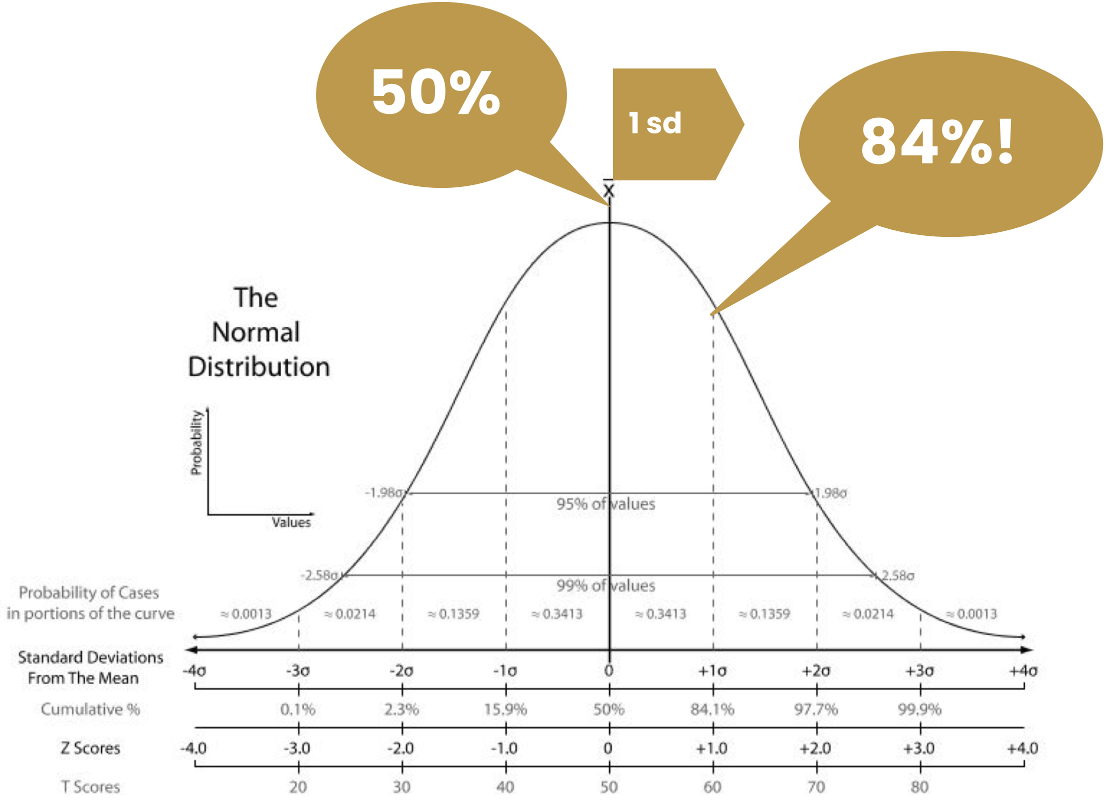
Source: E-learning and the Science of Instruction, Clark and Mayer, 4th ed., 2016

The impact is not small!!



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Evidence-based guidelines start from how expertise gets acquired

Stage	Implications for Instructional Design
Declarative	Clear **information** displays, e.g., job aids, examples, reference material
Procedural	Build varied **Practice tasks,** and **rich feedback/coaching**
Automated	**Repeated frequent practice** to build speed and accuracy

Research gives us guides to help with hard outcomes

Knowledge Component		Practice/Assessment
Procedure		Decide when to use; perform the steps
Supportive Knowledge	Fact	Recall fact in task context; spaced repetition
	Concept	Classify, identify or generate examples and non-examples
	Process	Identify causes of faults in a process; predict events in a process
	Principle	Decide if principle applies; predict an effect; apply principle to solve a problem, explain a phenomenon or make a decision

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Source: Koedinger, K. R., Corbett, A. T., & Perfetti, C. (2012). The Knowledge-Learning-Instruction framework: Bridging the science-practice chasm to enhance robust student learning. *Cognitive science*, 36(5), 757-798.

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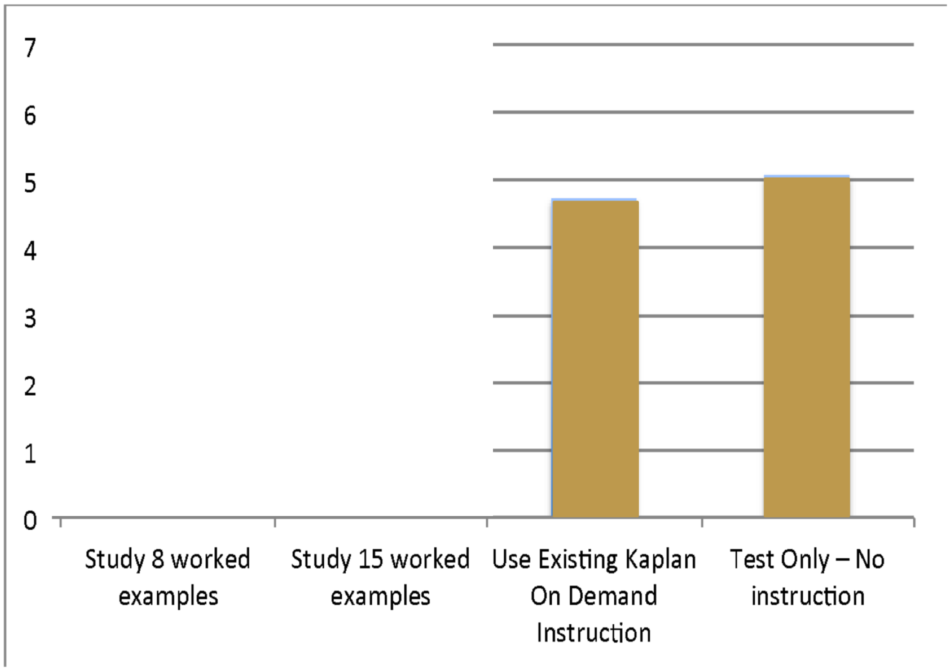
Evidence shows our intuitions aren’t the best guides



LSAT Logical Reasoning example

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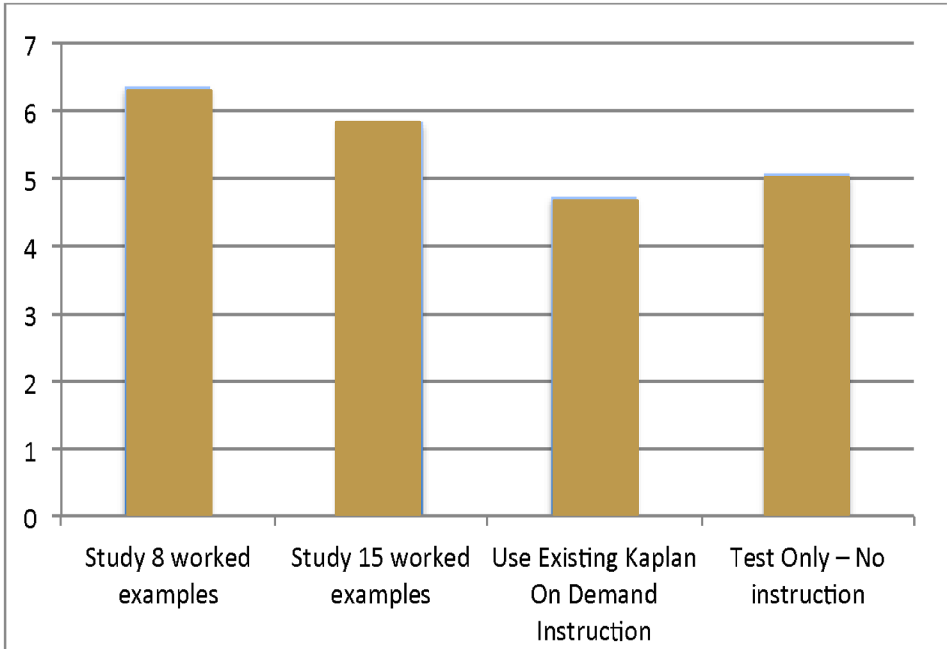
LSAT Logical Reasoning example



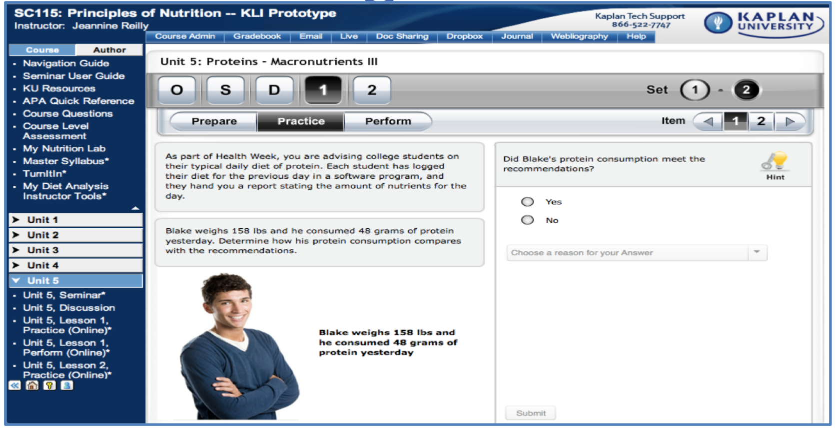
N	**153***	**148***	**107**	**84**
Time (mins)	**8.2**	**12.8**	**99.3**	**NA**

* Significant difference from "No Instruction"

More use of learning science principles does help

Existing courses

Redesigned courses



Read, Write, Discuss

- Outcomes and content not precisely aligned
- Limited demonstrations, worked examples, and practice
- General assessment rubrics
- High reliance on discussion boards

Prepare, Practice, Perform

- Outcomes and content aligned
- One lesson per objective
- Demonstrations and worked examples
- Practice, feedback before assessment
- Detailed scoring guides
- Less discussion/more practice
- Standard instructor materials
- Monitoring and support for motivation

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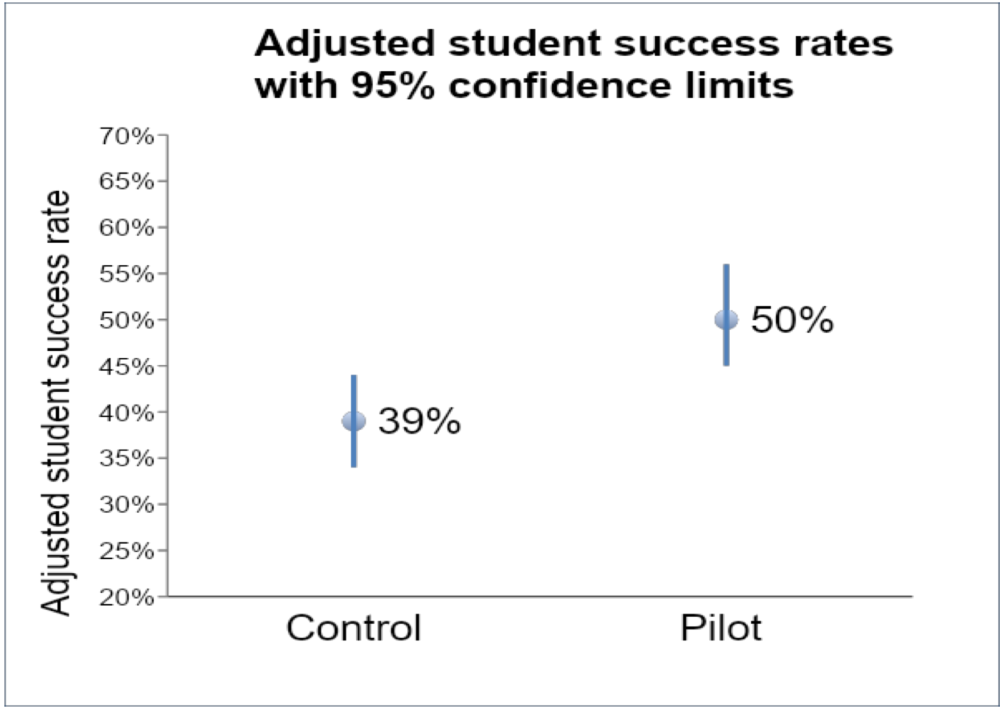
Result: much greater student success

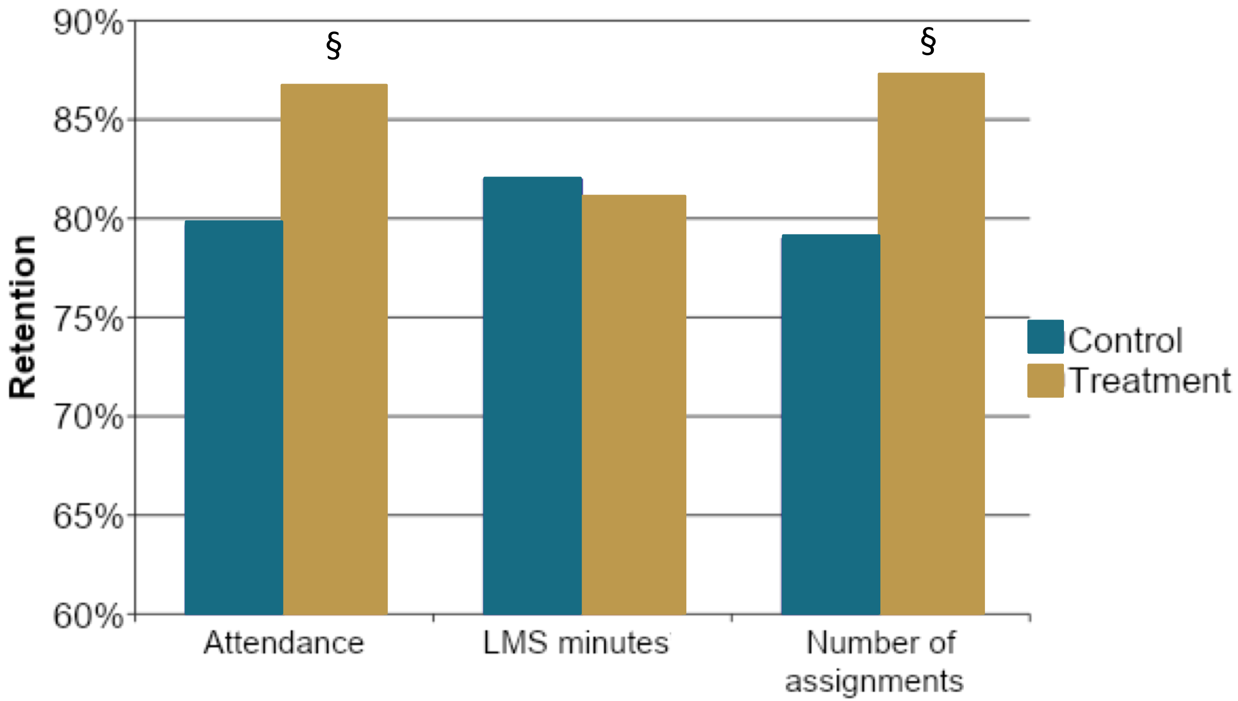


Wald Chi-Square: 10.42, df=1, n=895, Sig<.001.

- **11%** higher success rate
- **28%** increase
- Students in redesigned courses were **1.6** times more likely to be successful

We also need to check the tools we give to teachers/trainers

Impact of faculty dashboards on first year college social studies course



N: 653 625 498

§ Improved retention
* Improved learning outcomes

Lessons from CMU

- Work by Ken Koedinger’s team
- Drawing on large real-world course data sets in DataShop
- Shows a remarkable regularity!

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Selected CMU Datashop datasets have validated knowledge component models

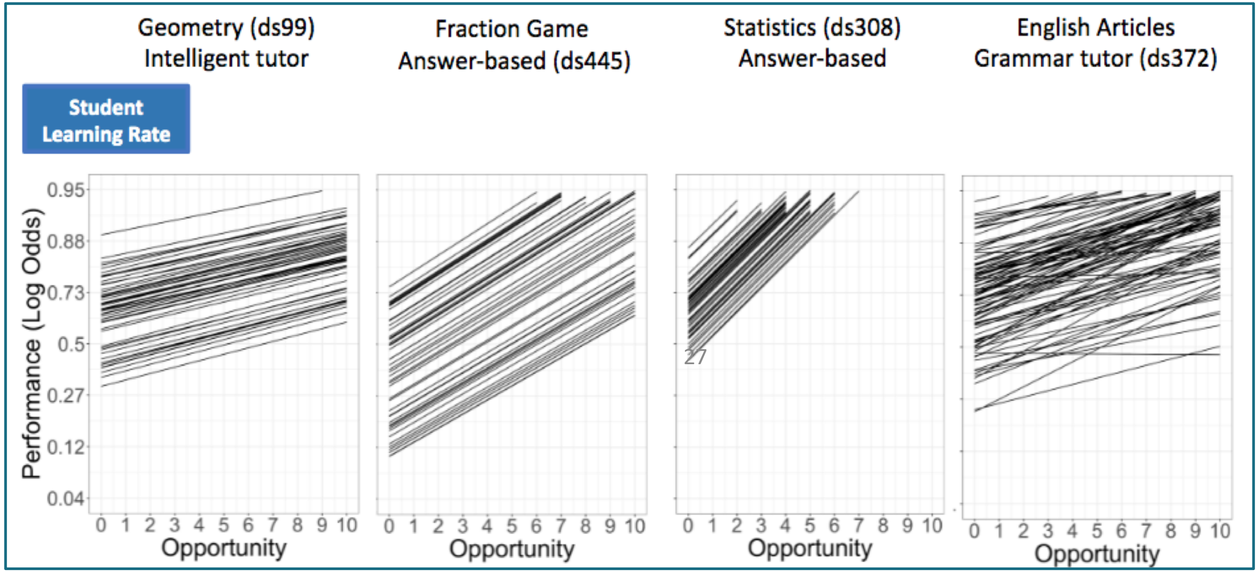
- **Different courses, with many students going through them**
- **Courses were improved over time - knowledge components (KCs) well-modeled and validated**

Dataset	Domain	Approx Grade Level*	Stu	Observations	#KC Models	KCs
ds115	Chinese	College	72	19,008	4	248
ds1387	Math/Other	Upper Elem	84	4,032	3	34
ds445	Fraction number line	Upper Elem	51	4,327	22	21
ds1980	English articles	Adult	120	6,592	25	16
ds394	English articles	Adult	97	5,773	12	13
ds1935	STEM	College	41	8,631	9	18
ds308	College Statistics	College	52	4,152	9	9
ds392	Geometry	Middle	123	41,756	8	38
ds1899	Math	Middle	302	4,930	9	6
ds372	English articles	Adult	99	7,128	16	19
ds99	Geometry	High	95	17,469	20	41
ds567	Fractions	Upper Elem	59	48,501	21	236
ds565	Fractions	Upper Elem	61	57,948	7	78
ds1007	Math/Other	Adult	49	5,063	9	4
ds447	Language	College	161	92,067	4	46
ds271	Math	Middle	69	1,103	5	6
ds563	Fractions	Upper Elem	64	55,407	17	54
ds253	Geometry	High	41	14,875	17	22
ds4555	Algebra	High	129	32,125	3	26
ds1943	Geometry	Middle	218	136,354	4	64
ds531	Language	College	77	117,297	5	68
ds562	Fractions	Upper Elem	63	48,739	21	102
ds566	Fractions	Upper Elem	58	64,025	9	60
ds406	Computer Science	College	765	441,643	5	74
ds564	Fractions	Upper Elem	73	66,728	9	65
ds1330	Algebra	Middle	3819	39,369	4	24
ds104	Physics	College	104	6,069	6	13

Within such courses, very little student-to-student learning rate variation. Only difference is where they started from!

Parallel lines indicate little difference in learning rate

Intercept differences indicate large differences in initial performance



Source: Koedinger, K. R., Carvalho, P., Liu, R., & McLaughlin, E. A. (2023). An Astonishing Regularity in Student Learning Rate. (https://psyarxiv.com/pxsfh/download?format=pdf)

High levels can be reached by all learners, given access to well-designed instruction and motivation for enough practice opportunities!

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Thank You

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