

An Illustration of an AI-based Educational Assistant and Its Underlying Learning Analytics



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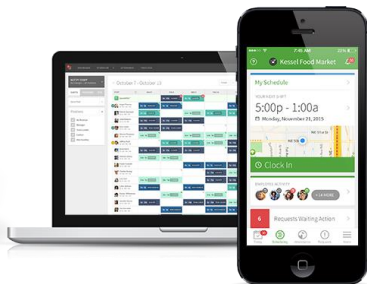
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ACTNext by ACT, Inc.

- **ACTNext:**
 - Multidisciplinary innovation unit at ACT established in September 2016
- **Computational Psychometrics:**
 - Theory and data driven methodology blending psychometrics and learning sciences, AI & Machine Learning, and data visualization
- **Mission**
 - Provide learners with transformational tools and experiences that are integrated, personalized and adaptive
 - Develop innovative solutions to challenging problems
 - Change the traditional notion of assessment from the ground up



The Future is Already Here: The Ubiquitous Presence of the AI-Assistants



- Posing questions to Siri and Alexa
- Reminders you might receive from a scheduling app
- Tracking and improving the quality of your sleep
- Personalized health recommendations
- Autonomous vehicles

Educational AI-Assistants

- Characteristics: Curation, Diagnostic, Recommendation, Learning
- **Good AI-assistants** = good recommendations and curation methods for one domain (say, a typical **Intelligent Tutoring Systems**)
- **More accomplished AI-assistants** = the ability to curate and provide recommendations covering more knowledge domains (say, **Watson**, or our **ACTNext Educational Companion**)
- **More sophisticated AI-assistants** = Learn & apply information from one domain to another (**The Holodeck**)



What's a Researcher To Do?

Develop and maintain the invisible infrastructure

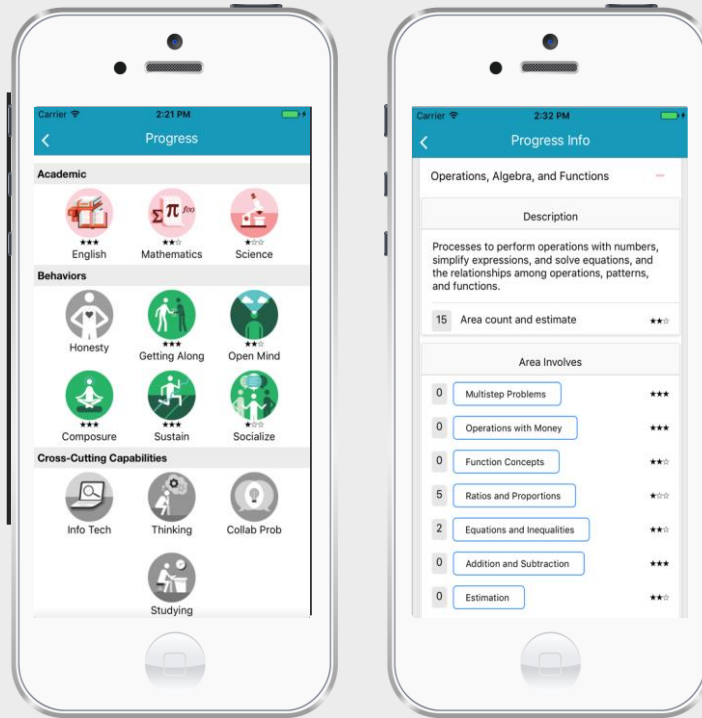
- Work with educators to:
 - Understand their needs
 - Incorporate best practices
 - Ensure efficacy, validity and fairness of the AI-Assistants
- Ensure that the AI-assistants skills are based on the learning science & psychometric theory



ACTNext: Educational Companion App

Novel Infrastructure: ML-based Curation & Tagging, Computational Psychometrics,
Data Cube, Diagnostic & Recommendation

ACTNext Educational Companion



Help Students

- Work to improve their scholastic performance
- Prepare for tests
- Engage in self discovery (what careers they may like, what personality traits they possess)

Provide

- Diagnostic information
- Feedback
- Personalized educational resources
- A test-bed for capabilities

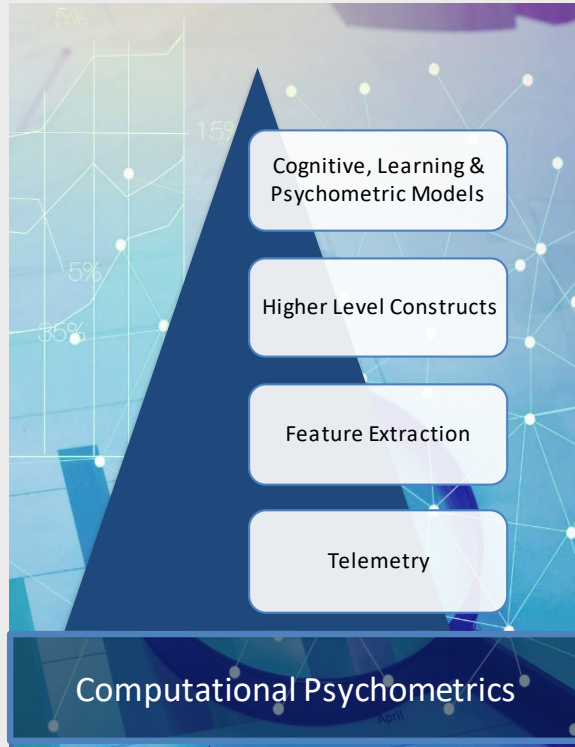
Educational Companion App Overview

Short, 2.5 minute
overview

[https://vimeo.com/31084
2023](https://vimeo.com/310842023)

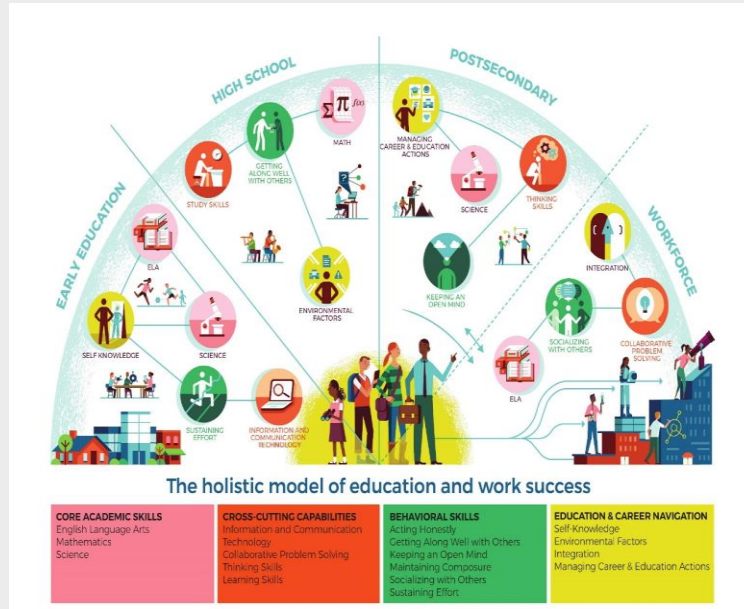


Computational Psychometrics



- CP is a blend of theory-driven psychometrics & machine learning methods used to measure latent abilities in real time.

ACT Holistic Framework

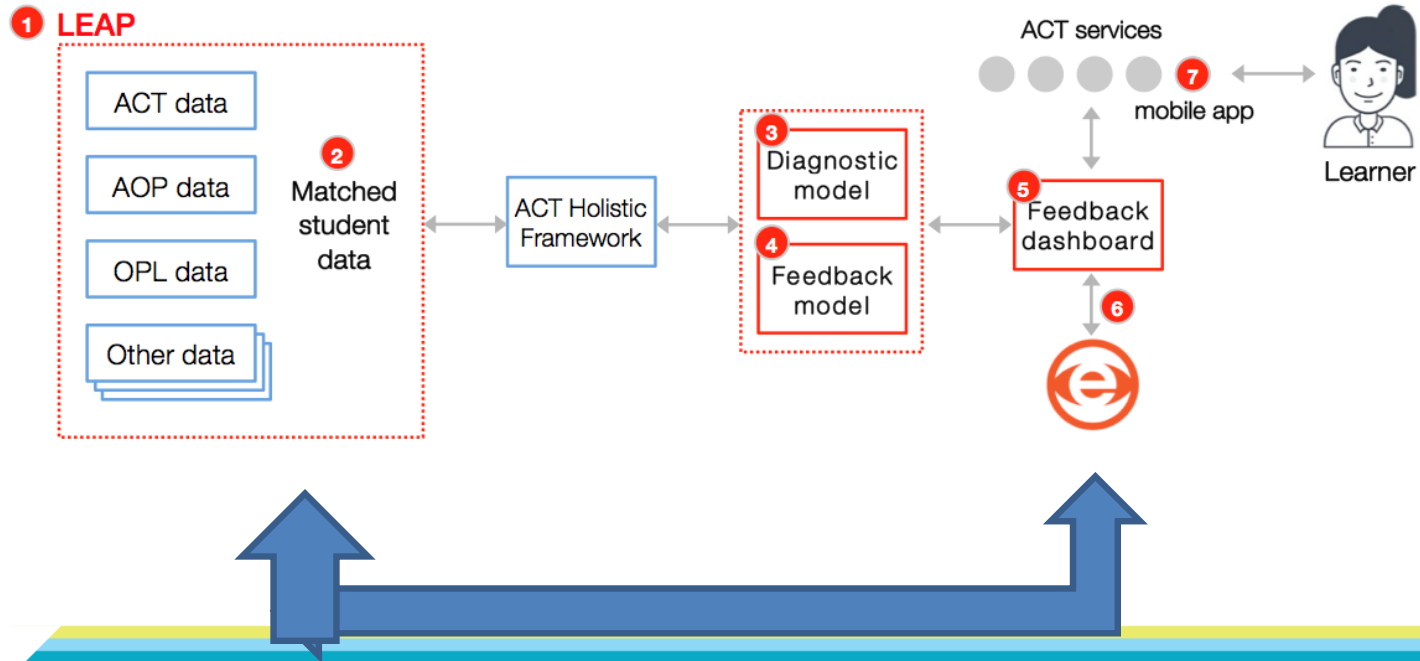


An integrated picture of education and work readiness organized into four broad categories

- navigation score academic skills
- cross-cutting capabilities
- behavioral skills
- education and career skills

“Missing Link” Concept

Designing a better value chain for Learning and Assessment Data



Data Considerations

- Probably all testing organizations have a 20th century data governance (separate collection & storage by administration)
- Legacy systems

- The ACT data are (for the most part)
 - From reliable & valid assessments
 - Consent for learning analytics & research at ACT has been provided by the test takers
 - Data protection measures are in place
 - Data linkage should be appropriate*

- The new types of data (learning & process data) need more research on
 - Reliability
 - Efficacy
 - Validity

- IMS standards are in place (for the most part)

The Data Cube

- ...is not a new idea (started in marketing 10 years ago)
- ...is a computational psychometrics approach
- ...is a data governance (for collection & storing)

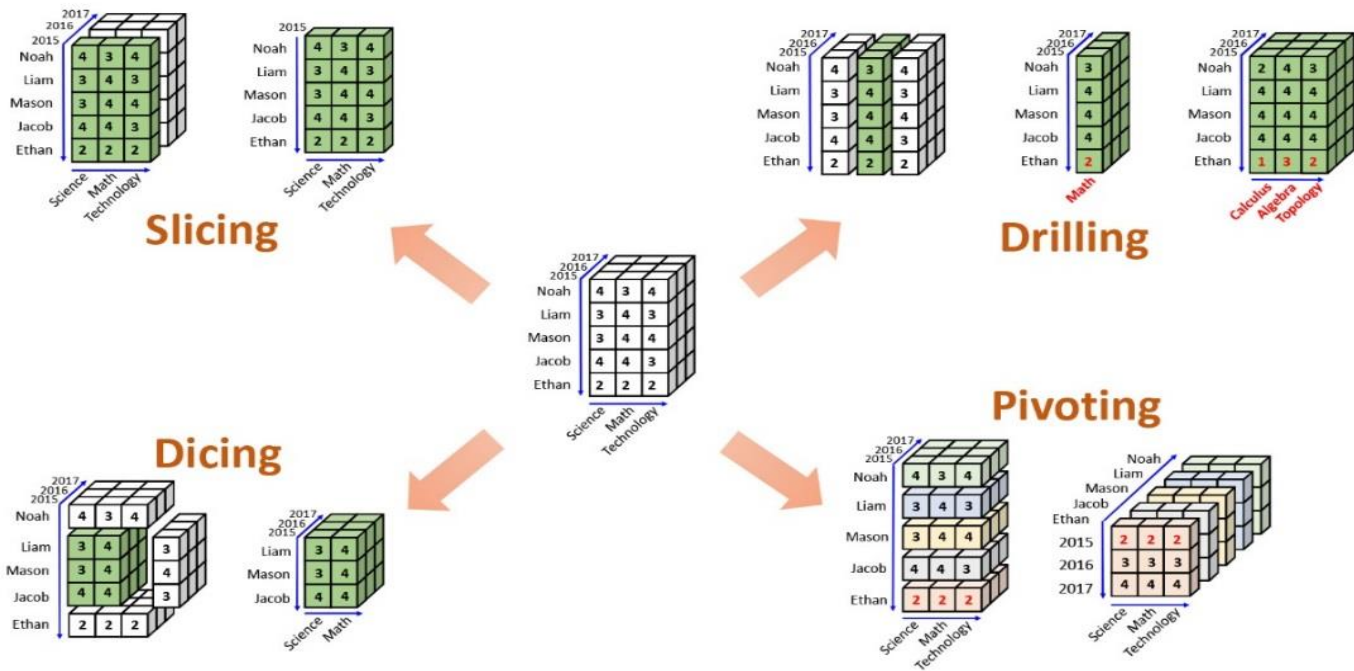
- Helps integrate and align the data sources & DB

- There are new psychometric questions to be addressed
 - How to fuse the data?
 - How to establish the standards to support alignment?
 - What models to apply to a mixture of data formats (continuous, discrete, stationary, non-stationary)

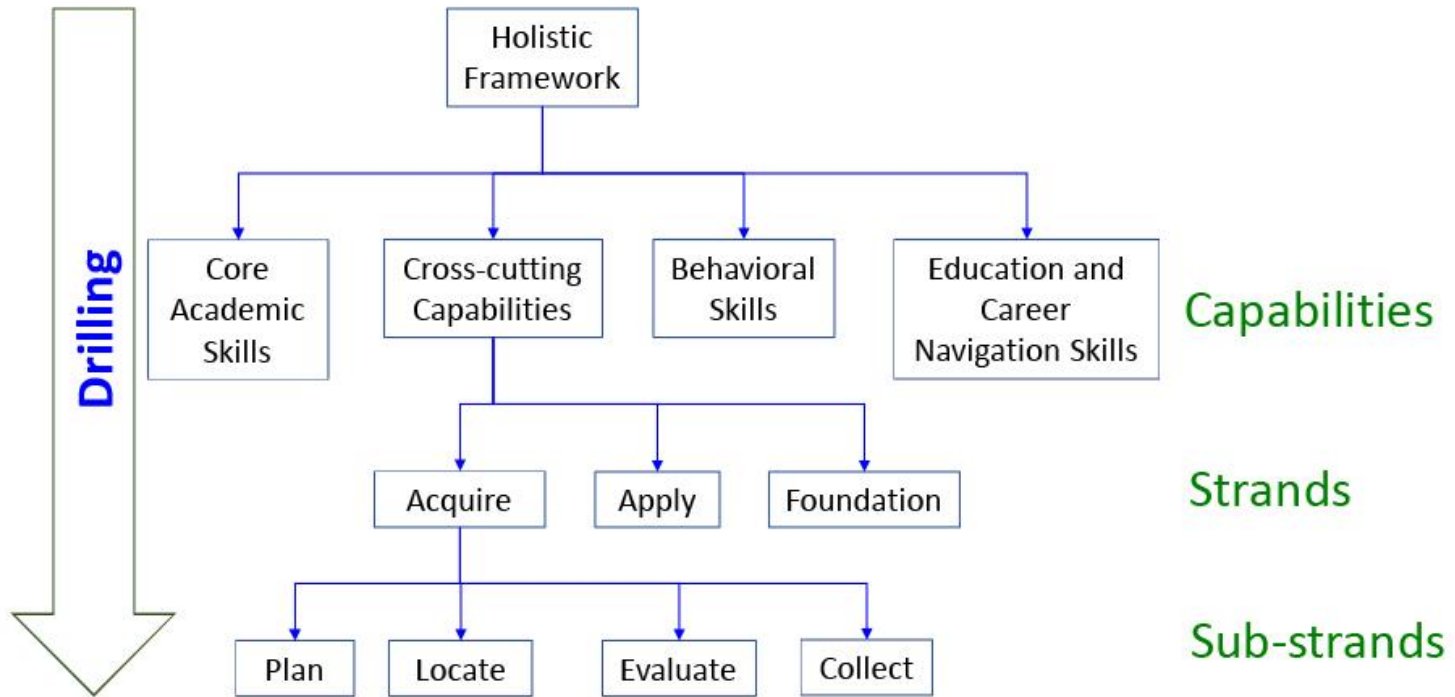
A New Consideration for the Data Cube

- Treat taxonomies/standards/knowledge maps as data (as in an NLP framework)
 - => tagging
 - => classification
 - => build Q-matrices
- Combine with item & instructional content metadata
 - =>align the testing instruments and the instructional tools (videos/items/hints) via the taxonomies

Example of “data projection operations”



Example of Application



ACT Academy

Companion app

HERA

Student CDM

Adaptive Testing

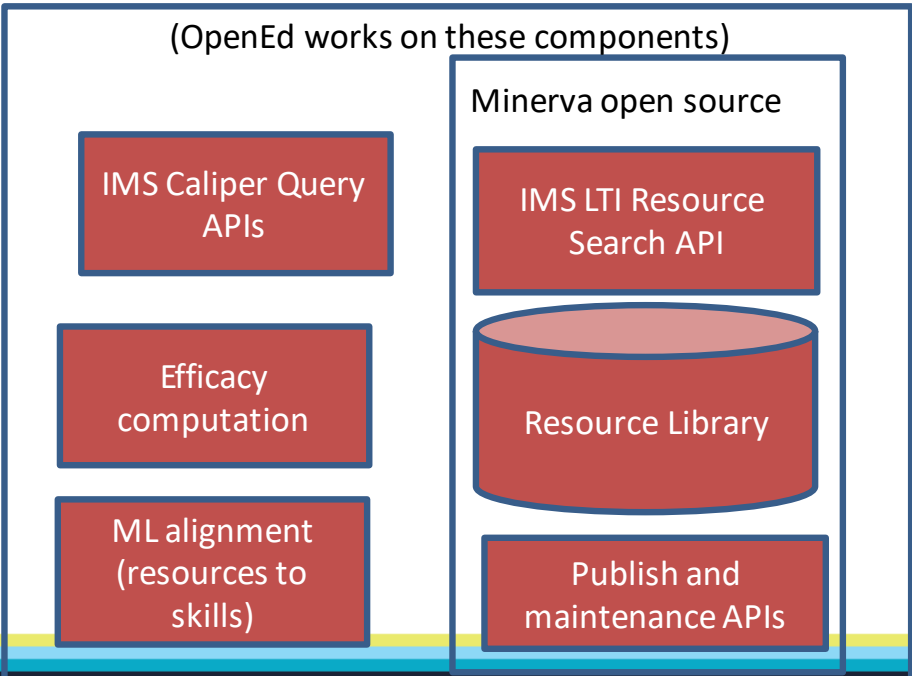
ACTNext Adaptive Learning Components

Recommendation engine

Automatic Test Assembly

LEAP
(analytics and repository of Learner usage and events)

Repository of skills and standards (OpenSALT)



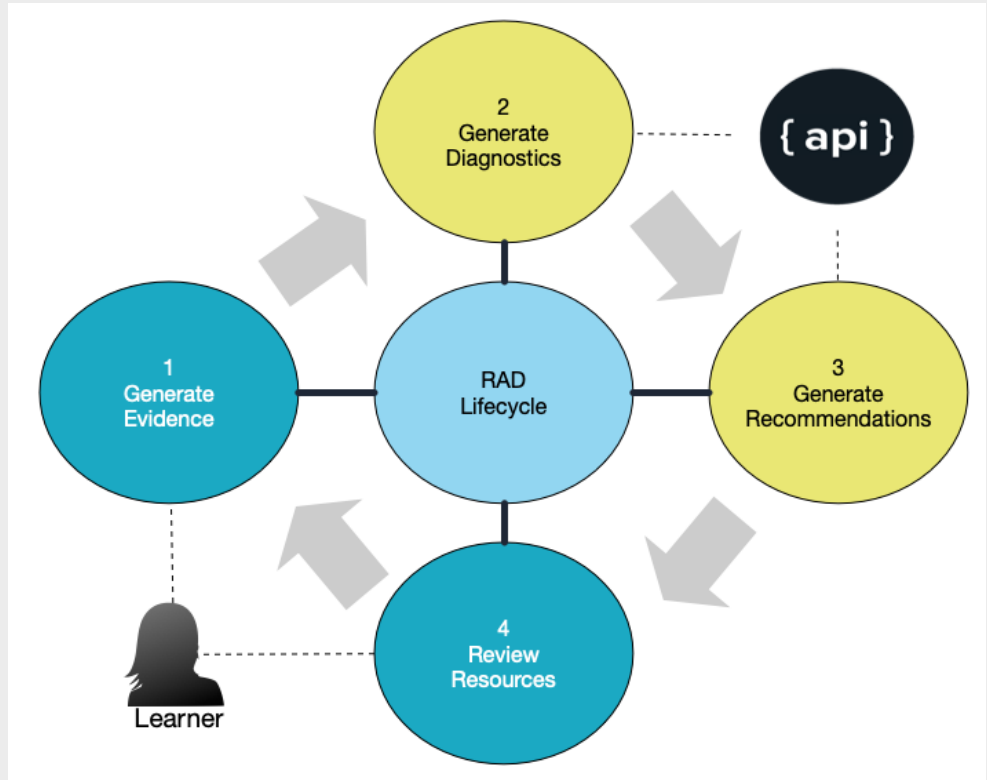
Computational Psychometrics for Diagnostic & Feedback

- **Cognitive Diagnostic Models (CDM)** were developed in the field of psychometrics for the assessment of subskills using traditional tests
- **Learning models (LM): Examples Elo Ranking or Bayesian Knowledge Tracing (BKT)**. Developed in the Educational Data Mining field for Intelligent Tutoring Systems (ITS)
- **Learning Analytics (LA)** was adapted from the business analytics field to use ancillary information to provide guidance
- **ACTNext Approach:** Integrate CDM-like models, LM, and LA to construct a dynamic Cognitive Diagnostic Model for Learning & Assessment Systems, [dCDMLAS](#)

Companion App Technologies

- App built using React Native
<http://www.reactnative.com>
 - Originally developed by Facebook
 - Supports both Apple iOS and Android platforms/stores
 - Back-end services are hosted at Amazon Web Services
 - Resource Bundles are used to support translations of the application to multiple languages

Companion App/ RAD API Architecture



Companion App/RAD Models & Algorithms

Total of 20+, including variants

- 1 MAJORITY CLASS**
(always correct)
- 2 IPL IRT**
- 3 LLTM**
Linear Logistic Test Model
- 4 AFM**
additive factors model (with learning rates)
- 5 PFA**
performance factors analysis (with learning rates)
- 6 BKT**
Bayesian knowledge tracing model (with learning rates)
- 7 ELO MODELS**
many, accounting for students, items, skills (multiple per item), subject, student-skill interaction, etc.
- 8 URNINGS**
(multiple variants)

ELO OUTCOMES VIA ITEM RESPONSES



LEARNER

Jane Smith
Hier. Skill Elo: 0.769



H.A.LAL.CC.2.1.1



SKILL

Scan for and locate key details in the text
Hier. Skill Elo: 0.367

Diagnostic Modeling in RAD API

- Options for the diagnostic model: Data-driven Design (D3)

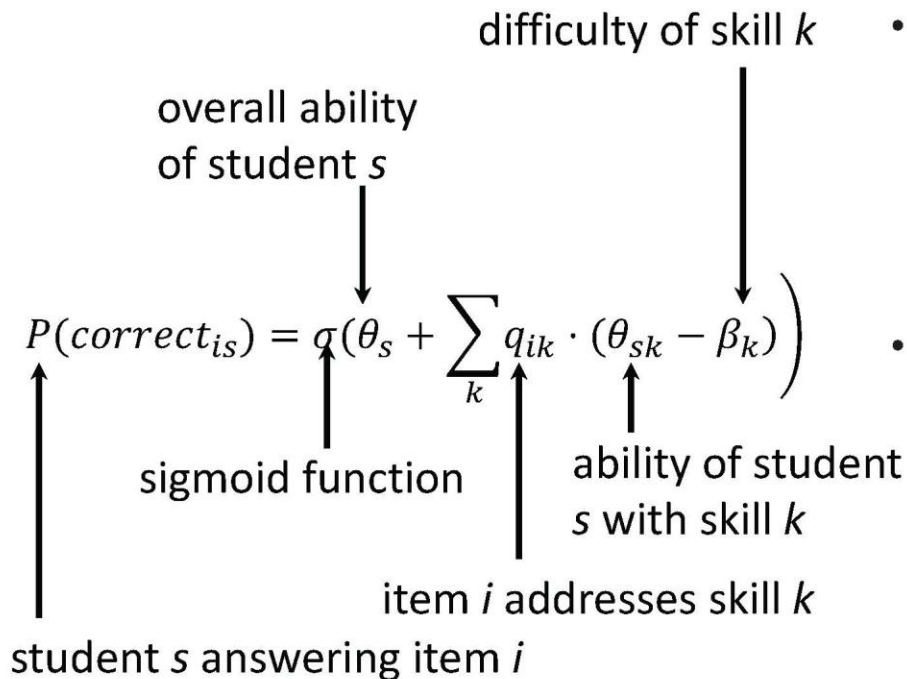
Model Type	Model	No. par.-s	Cross-validation	Note
Null	Majority Class	0	N/A	Sanity check
Psychometric (assessment)	1PL IRT†	1+I †	✓	A must baseline to surpass, or is it?
	LLTM	1+K †	✓	
Rating schema	Elo & variants	3+	✓*	⊕ cold start, ⊕ extensibility, ⊖ lack of theoretical guarantee
	Urning's & variants	4+	✓*	⊕ theoretical guarantee, ⊕ extensibility, ⊖ computational complexity
Learning	AFM + variants	1+2*K+ †	✓	⊕ extensibility
	PFA + variants	1+3*K+ †	✓	
	BKT + variants	4*K+ †	✓	⊕ interpretability, ⊕ extensibility

K – number of skills, I – Number of question items/problems

† – student ability parameters are treated as random effect and thus contribute 1 to the total number of parameters

* – limited ability to cross-validate, only student-stratified

Elo – RAD API's diagnostic model (1)



- Why Elo?
 - Students try broad set of skills (models of learning do not perform well)
 - Based on psychometric LLTM
 - Local updates
 - Very few hyper-parameters
- Why this type of Elo?
 - Hierarchical structure of abilities
 - Highly accurate

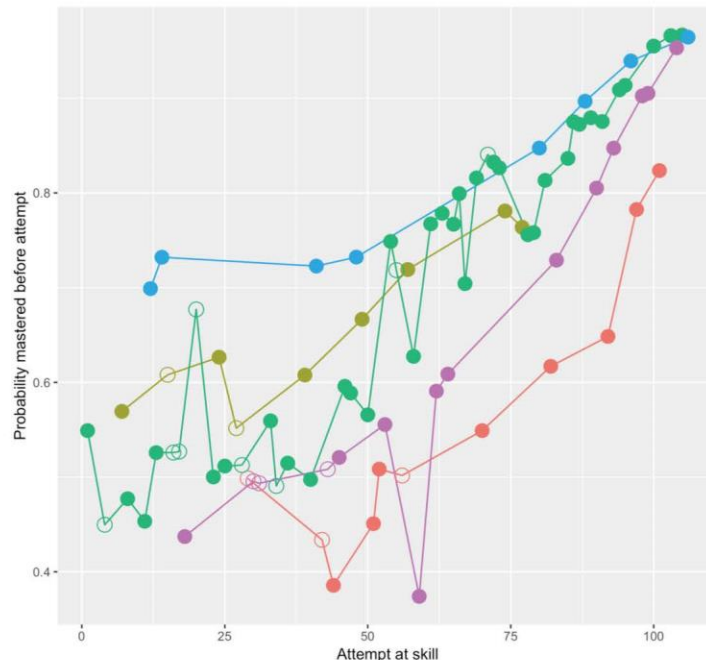
Elo – RAD API's diagnostic model (2)

- Updates to tracked values
 - Tracked values start at 0
 - Use uncertainty ratio as sensitivity multiplier
 - 6 hyper-parameters overall

$$\theta_s = \theta_s + \frac{a_s}{1 + b_s n_s} \cdot (\text{correct}_{is} - P(\text{correct}_{is} = 1))$$

$$\theta_{sk} = \theta_{sk} + \frac{a_{sk}}{1 + b_{sk} n_{sk}} \cdot (\text{correct}_{is} - P(\text{correct}_{is} = 1))$$

$$\beta_k = \beta_k - \frac{a_k}{1 + b_k n_k} \cdot (\text{correct}_{is} - P(\text{correct}_{is} = 1))$$



ACT Academy Dashboard Resources Progress Time & Statistics

You have 1 stars in Math overall. Let's break it down.

Number & Quantity ★☆☆ Mastery Level Take Quiz Get Resources	Algebra ☆☆☆ Mastery Level Take Quiz Get Resources	Functions ☆☆☆ Mastery Level Take Quiz Get Resources	Geometry ☆☆☆ Mastery Level Take Quiz Get Resources
Statistics & Probability ☆☆☆ Mastery Level Take Quiz Get Resources	Integrating Essential Skills ☆☆☆ Mastery Level Take Quiz Get Resources	Modeling ☆☆☆ Mastery Level Take Quiz Get Resources	

Already taken the ACT Test once and practicing for round two? [Enter your scores](#) and skip these quizzes.

RAD METRICS

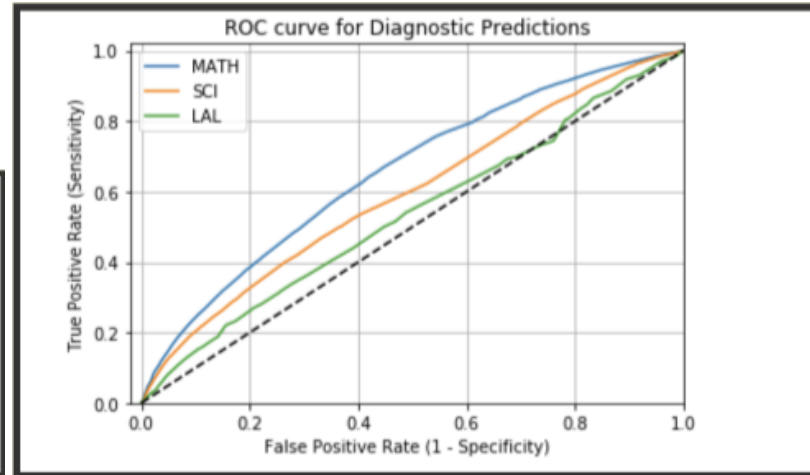
RAD Metrics

Steve Polyak, PhD, Benjamin Deonovic, PhD
Michael Yudelson, PhD, Kurt Peterschmidt

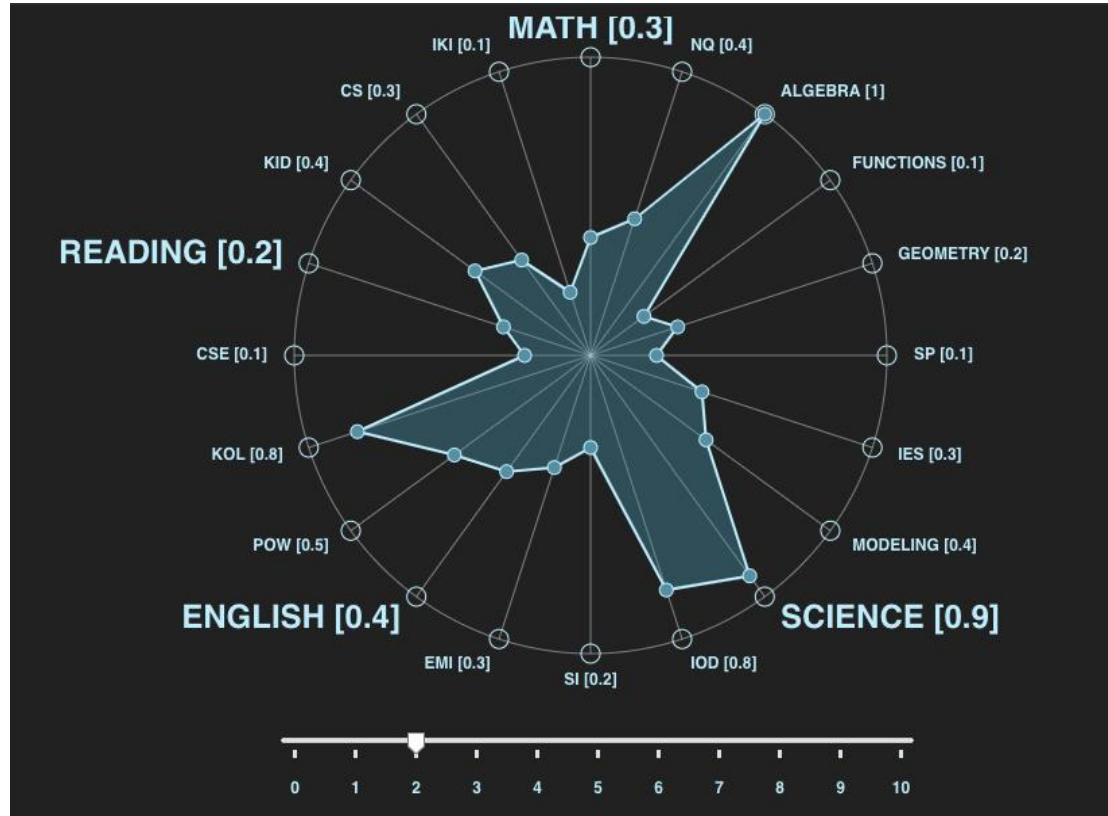
November 2018

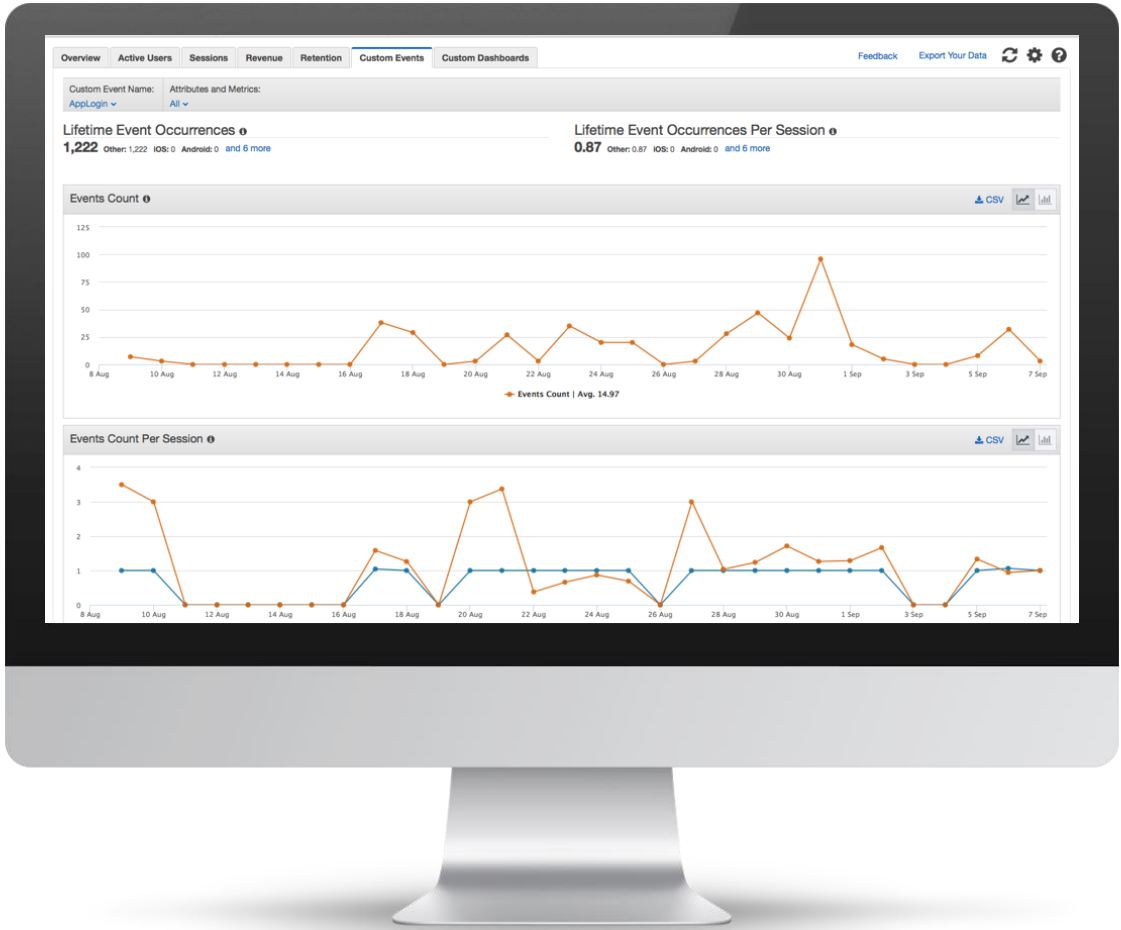
1 Introduction

ACTNext is a research & development, innovation group at ACT, Inc. ACTNext's research involves the use of advanced psychometrics, machine learning techniques and algorithmic development based on the application of Artificial Intelligence in the education/learning



RAD REPLAYS





Daily Active Students

Week of Ev..	M	T	W	T	F	S	S	Grand Total
18-Sep			42	14	5	2	3	44
25-Sep	3	1	2	3				8

Displayed Cohort:
11th Grade

44 Total Students

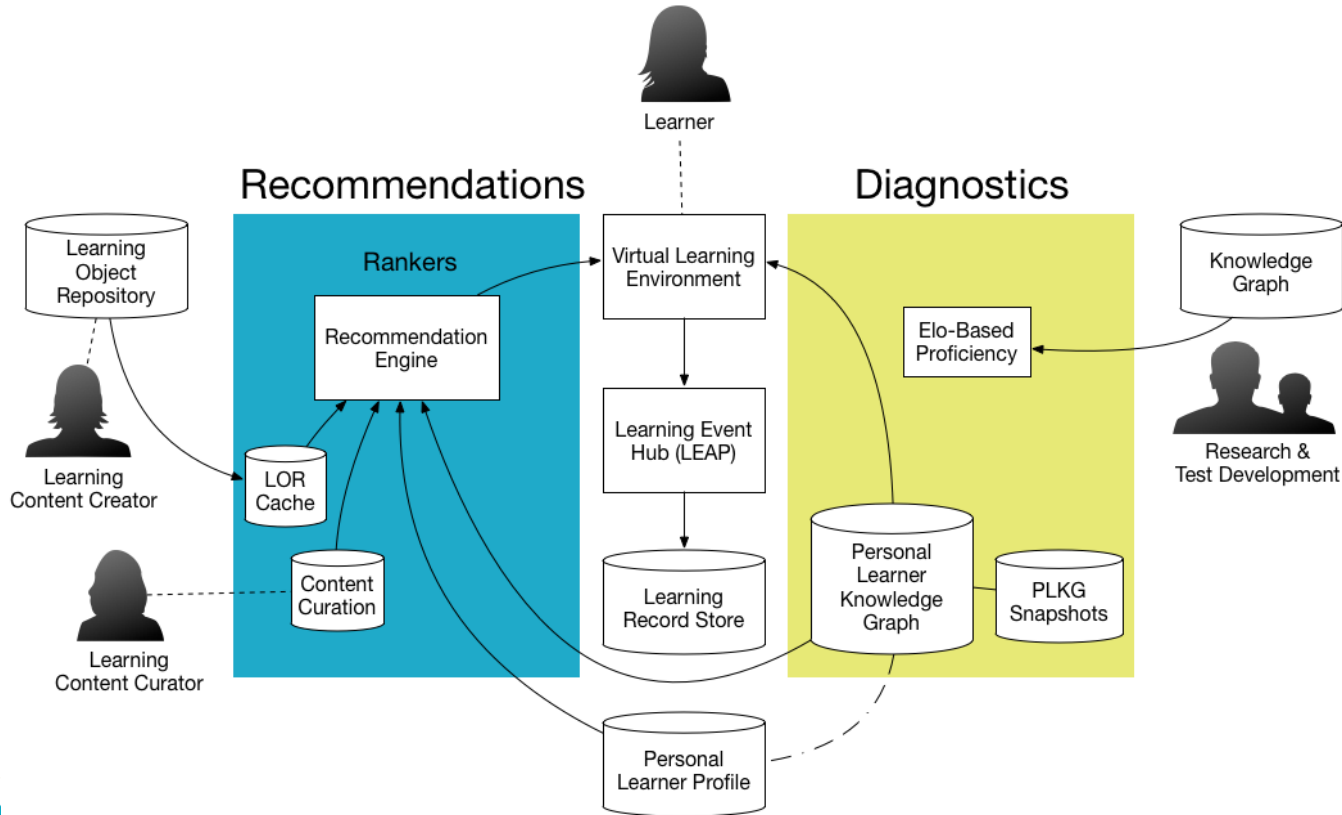
Roster

Activities

Unique Resources by Week

Total Views by Week

Roster	Activities				Unique Resources by Week						Total Views by Week						
	OE	II	CS	CR	ELA		MATH		SCI		ELA		MATH		SCI		
	Last	This	Last	This	Last	This	Last	This	Last	This	Last	This	Last	This	Last	This	
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Future Work & RAD API

- Companion prototype provided foundation for the ACT Recommendation and Diagnostic Application Programming Interface (RAD API)
- A test-bed for additional capabilities (text-to-voice; translations)
- The RAD API tracks evidence of learning in real-time, diagnoses mastery levels & generates personalized recommendations
- The RAD API is a scalable ACT SaaS capability:
 - *Can be aligned to any set of standards*
 - *Plugged into any learning platform*
 - *Currently integrated into ACT Academy*
- The RAD API is the engine driving the future of adaptive, personalized learning at ACT
- RAD is fully integrated into ACT Academy

A Hippocratic Oath for Educators and Edtech Communities

The technology (if not fully baked) already exists, it's just a matter of refinement

Edtech communities and Educators share a unique role and responsibility in the development of AI education assistants and the impact they will have on learners everywhere

Thank You



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- Pilot study: Cinton Highschool, SC