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

ACTNext by ACT, Inc.

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• **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 posses)

Provide
- Diagnostic information
- Feedback
- Personalized educational resources
- A test-bed for capabilities
Educational Companion App Overview

Short, 2.5 minute overview

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, discreet, 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

- Holistic Framework
  - Core Academic Skills
  - Cross-cutting Capabilities
  - Behavioral Skills
  - Education and Career Navigation Skills
    - Acquire
    - Apply
    - Foundation
      - Plan
      - Locate
      - Evaluate
      - Collect

Capabilities
Strands
Sub-strands
Minerva open source

Efficacy computation

Resource Library

IMS LTI Resource Search API

Publish and maintenance APIs

ML alignment (resources to skills)

IMS Caliper Query APIs

Recommendation engine

Automatic Test Assembly

Student CDM

Adaptive Testing

ALEP (analytics and repository of Learner usage and events)

LEAP (analytics and repository of Learner usage and events)

Repository of skills and standards (OpenSALT)

(OpenEd works on these components)

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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](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. 1PL 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.L.A.L.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)

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Model</th>
<th>No. par.-s</th>
<th>Cross-validation</th>
<th>Note</th>
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<td>Sanity check</td>
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<td>1+I †</td>
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<tr>
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<td>Elo &amp; variants</td>
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<td>✓*</td>
<td>☀ cold start, ☀ extensibility, ☹ lack of theoretical guarantee</td>
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<tr>
<td></td>
<td>Urnings &amp; variants</td>
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<td>✓*</td>
<td>☀ theoretical guarantee, ☀ extensibility, ☽ computational complexity</td>
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<tr>
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<td>AFM + variants</td>
<td>1+2*K+ †</td>
<td>✓</td>
<td>☀ extensibility</td>
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<tr>
<td></td>
<td>PFA + variants</td>
<td>1+3*K+ †</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BKT + variants</td>
<td>4*K+ †</td>
<td>✓</td>
<td>☀ interpretability, ☀ extensibility</td>
</tr>
</tbody>
</table>

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)

\[ P(\text{correct}_{is}) = \sigma(\theta_s + \sum_k q_{ik} \cdot (\theta_{sk} - \beta_k)) \]

- 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

\[
\begin{align*}
\theta_s &= \theta_s + \frac{a_s}{1 + b_sn_s} \cdot (\text{correct}_{is} - P(\text{correct}_{is} = 1)) \\
\theta_{sk} &= \theta_{sk} + \frac{a_{sk}}{1 + b_{sk}n_{sk}} \cdot (\text{correct}_{is} - P(\text{correct}_{is} = 1)) \\
\beta_k &= \beta_k - \frac{a_k}{1 + b_kn_k} \cdot (\text{correct}_{is} - P(\text{correct}_{is} = 1))
\end{align*}
\]
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
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 field.
RAD REPLAYS
### Daily Active Students

<table>
<thead>
<tr>
<th>Week of Event</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>T</th>
<th>F</th>
<th>S</th>
<th>S</th>
<th>Grand Total</th>
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<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>25-Sep</td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
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</tbody>
</table>

Displayed Cohort: 11th Grade

### Unique Resources by Week

<table>
<thead>
<tr>
<th></th>
<th>ELA</th>
<th>MATH</th>
<th>SCI</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>This</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Total Views by Week

<table>
<thead>
<tr>
<th></th>
<th>ELA</th>
<th>MATH</th>
<th>SCI</th>
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<tr>
<td>This</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
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

Alina.vonDavier@act.org

@AlinaVdav

Acknowledgement
- Contributions: Steve Polyak, Kurt Peterschmidt, Benjamin Deonovic, Michael Yudelson, Gunter Maris
- Some of the pictures: Diana Oblinger
- Pilot study: Cinton Highschool, SC