Leveraging ideas from adaptive testing to adaptive learning

The HERA showcase

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Outline of the talk

- Introduction
  - Adaptive Testing
  - Adaptive Learning
- Ideas from adaptive testing and formative assessment
  - Adaptation by difficulty
  - Self-adaptation
  - Multi-stage Adaptivity
  - Assessing partial knowledge; hints & feedback
  - Learning progressions and diagnostic tests
  - Development framework: Evidence Centered Design
- Application: design of the HERA system (+demo if time allows)
- Findings from early pilot

Adaptive Testing: Intentions & Outcomes

- Goal: improve measurement
  - Increase reliability (reduce measurement error)
  - shorten tests
  - Maximize test information
  - Statistical models: primarily IRT

- Outcome: assign question at the ability level of test taker
  - Usually test takers will get items that they have a probability of 50% to answer them correctly
  - Usually, item selection is defined item-by-item
  - Item selection is by **difficulty**
  - ➔ Similar experience for all individuals (in terms of relative test difficulty)
  - ➔ high performing test takers are not bored, low performing are less frustrated

Adaptive Learning

- Tutoring systems
  - Adaptivity by content/skill
  - Rule-based or algorithm-based
    - Within task (step loop) vs. between tasks (task loop)
  - Mastery-model for knowledge
  - Provide feedback on correctness
  - May provide hints
  - Statistical models: mainly Bayesian Knowledge Tracing (BKT)

Ideas from Adaptive Testing and Formative Assessment

- Why and how ideas from assessment can leverage learning?
- Rigor methods for ensuring validity
  - Adaptation by difficulty; assessing ability on-the-fly
  - Self-adaptation – research findings
  - Multi-stage Adaptivity
  - Assessing partial knowledge; hints & feedback
  - Learning progressions and diagnostic tests
  - Development framework: Evidence Centered Design

Adaptation by difficulty; Assessing ability on-the-fly

- In contrast to adaptive learning (usually by content/skills)
- Ability assessed on-the-fly → ability measure reliable and valid
- Valid & stable measures of item difficulty (not just expert evaluation)
- Can be flexible – change the window of input to estimate ability (to allow measure of change/learning)
- Based on psychometric models (IRT; CDM); can also adopt Elo and Urning models / mathematically also linked to BKT (Deonovic et al., 2019)
- → can combine adaption by difficulty & skill (CDM)

Self-adaptation – Research Findings

- Giving test takers choice to choose the difficulty (Arieli-Attali, 2016; Rocklin & O'Donnell, 1987; Wise et al., 1992)
  - Test takers overall choose level of difficulty that corresponds to their ability level
  - Test takers overall choose difficulty of 65%-75% probability correct (CAT algorithm often selects items at 50% difficulty)
- If test takers are rewarded for difficulty of items – they tend to challenge themselves more

Multi-stage Adaptivity

- Instead of selecting item-by-item, can select a group of items (testlets) adaptively
- Content balanced
- Information Targeted at Cut versus at Ability
- Influence of Multiple Cut Scores
- Tree-based multistage adaptive

Assessing partial knowledge; hints & feedback

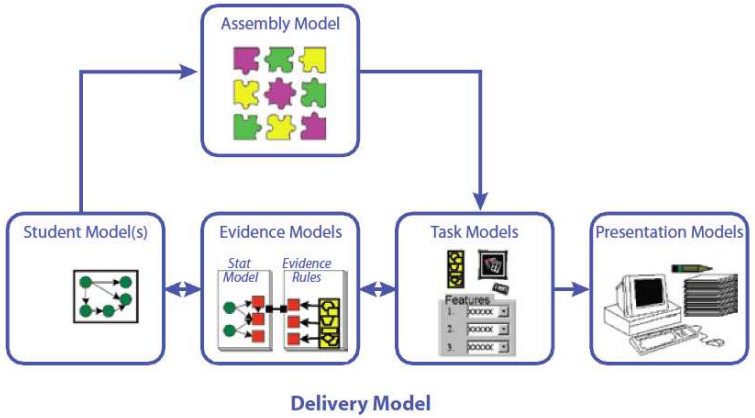
- Assessing partial knowledge (Ben Simon & Budescu, 1997)
- Assessing knowledge when feedback and multiple attempts are provided (Attali & Powers, 2010; Attali, 2011)
- Assessing knowledge/ability when hint is used (Bolsinova et al., 2019)

Learning progressions and diagnostic tests

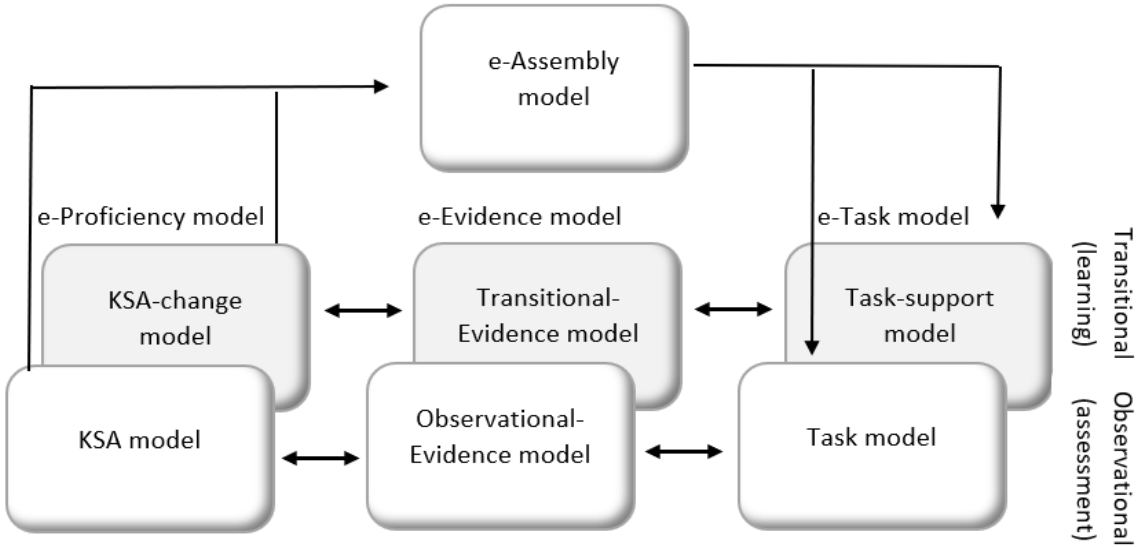
- Designing task models based on a map of skills that reflects progression ➔ student model
- Diagnostic models ➔ statistical models to diagnose where students are

Development framework: Evidence Centered Design

A Schematic Representation of the Models in the ECD Framework (Mislevy et al., 2006)



➔ Expanded framework



THE HERA SHOWCASE

Meet HERA !

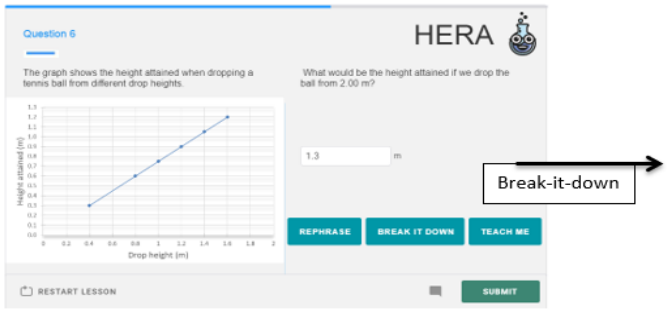
An Adaptive

- **H**olistic
- **E**ducational
- **R**esources and
- **A**ssessment System

for Science

--Research-based prototype
--Bridging assessment & learning
--Using science simulations as context
--Adaptive scaffolding (self-adaptive help options)
--Adaptive sequencing

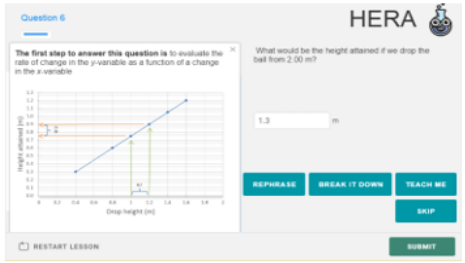
Task model from HERA
An item with scaffolds after incorrect response



Rephrase

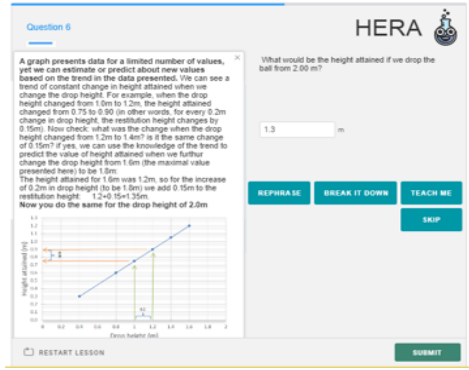
Target skill

Break-it-down



Proximal precursor (+ distal)

Teach-me



Initial + distal+ proximal

ACTNEXT BY ACT

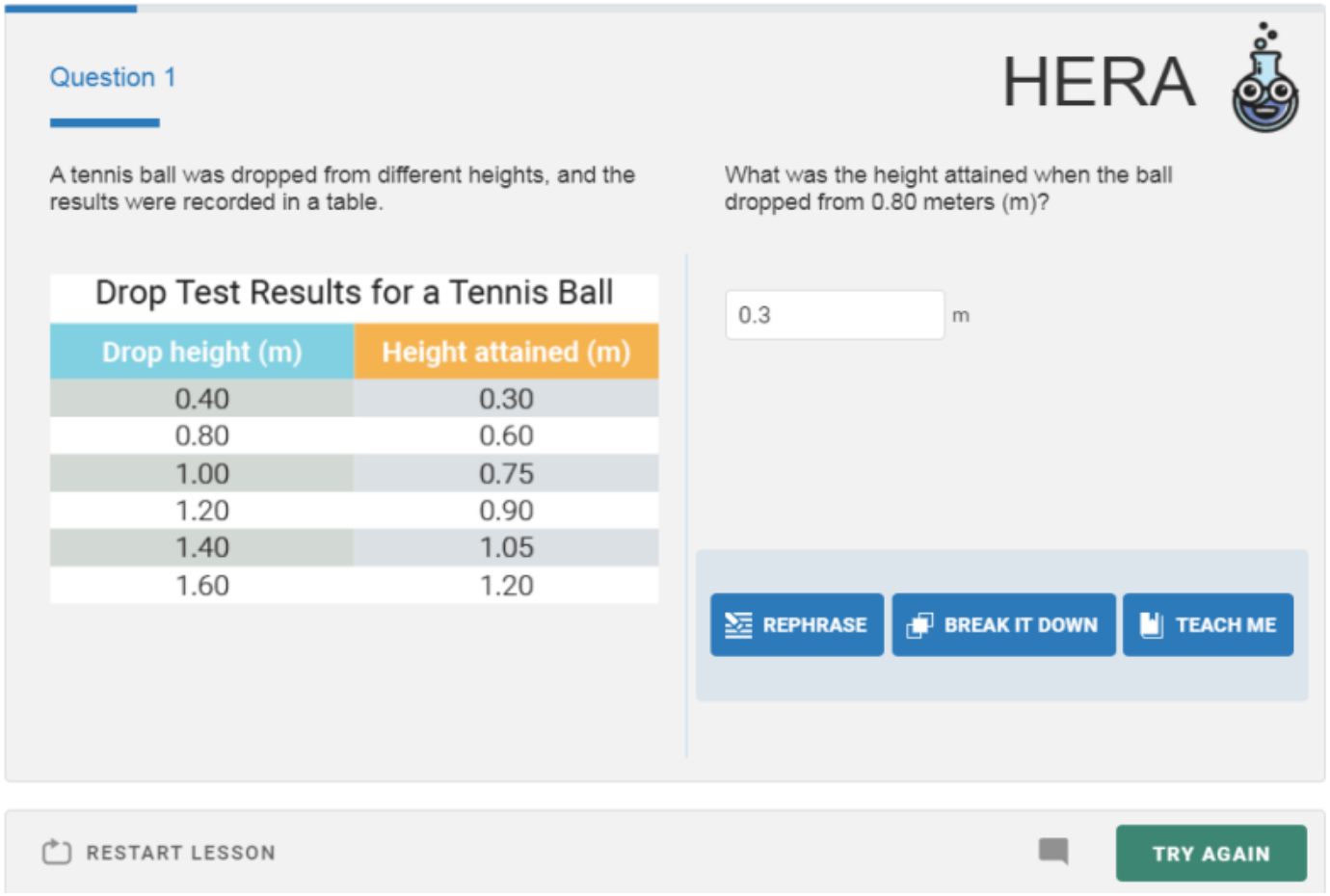
The HERA pilot

May-Aug 2018

- Collaboration between ACT, ACTNext, Smart Sparrow & PhET
- Pre-pilot in May 2018 – to examine functionality
- Large pilot in Aug 2018 – to examine learning-supports usage
  - Participants:
    - 2,775 Amazon Mechanical Turk; in 10 conditions; each participant completed 3 lessons
  - Materials:
    - Six lessons (Physics; Chemistry; Biology) - Four lessons include simulations as preview (two sims from PhET); Each lesson includes 10 items with learning supports
  - Conditions:
    - Examine different ways to offer learning supports: (1) before response or after; (2) with or without cost; and (3) with different cost systems

*Lessons topics: Restitution, Specific Heat, Hooke's Law, Beer's Law, Hinges, Self-pollination

Item with Learning Supports

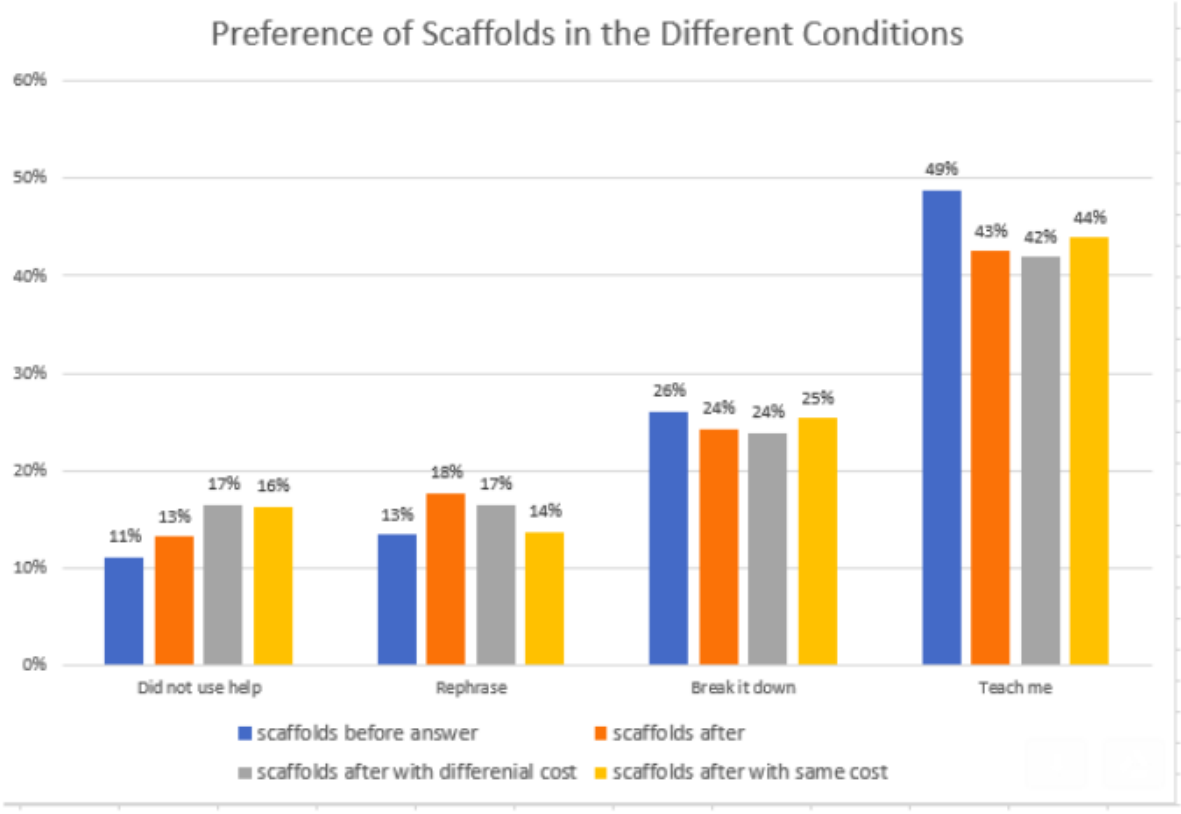


Learners can choose between three learning supports:
1 – Rephrase the question
2 – Break-down the question to steps
3 – Teach me the content by solved example or full explanation

Differential cost was:
Rephrase = 1 beaker
Break-it-down = 2 beakers
Teach me = 3 beakers

Equal cost :
2 beakers per support

Learners Preference of Learning Supports



Trends:

- Overall, learners prefer “Teach me” (on average 45%), over “Break-it-down” (on average 25%) and “Rephrase” (on average 15%).
- When scaffolds are offered ***before*** answer - learners are using more help, particularly more “Teach me” but less “Rephrase”.
- When scaffolds are offered at a ***cost*** – students use less help (by about 3%- 4% compared to no cost).
- When the cost is ***differential*** as 1-2-3, there is almost no change in the distribution compared to no cost; equal cost of 2-2-2 increases the use of “Teach me” in the expense of “Rephrase”

Summary

- We implemented ideas from CAT, MST and Self-Adapted tests; adaptivity by difficulty, content & student choice
- Adaptivity by units – based on multistage adaptive and balancing content
- Based on progression of skills and student maps (student model)
- Based on statistical models when using hints, feedback, & multiple attempts

Next steps

- Based on pilot with adults ➔ developing a prototype with more content
- Will pilot with middle school students in 2020

Thank you

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