Exploration of the Robustness and Generalizability of the Additive Factors Model

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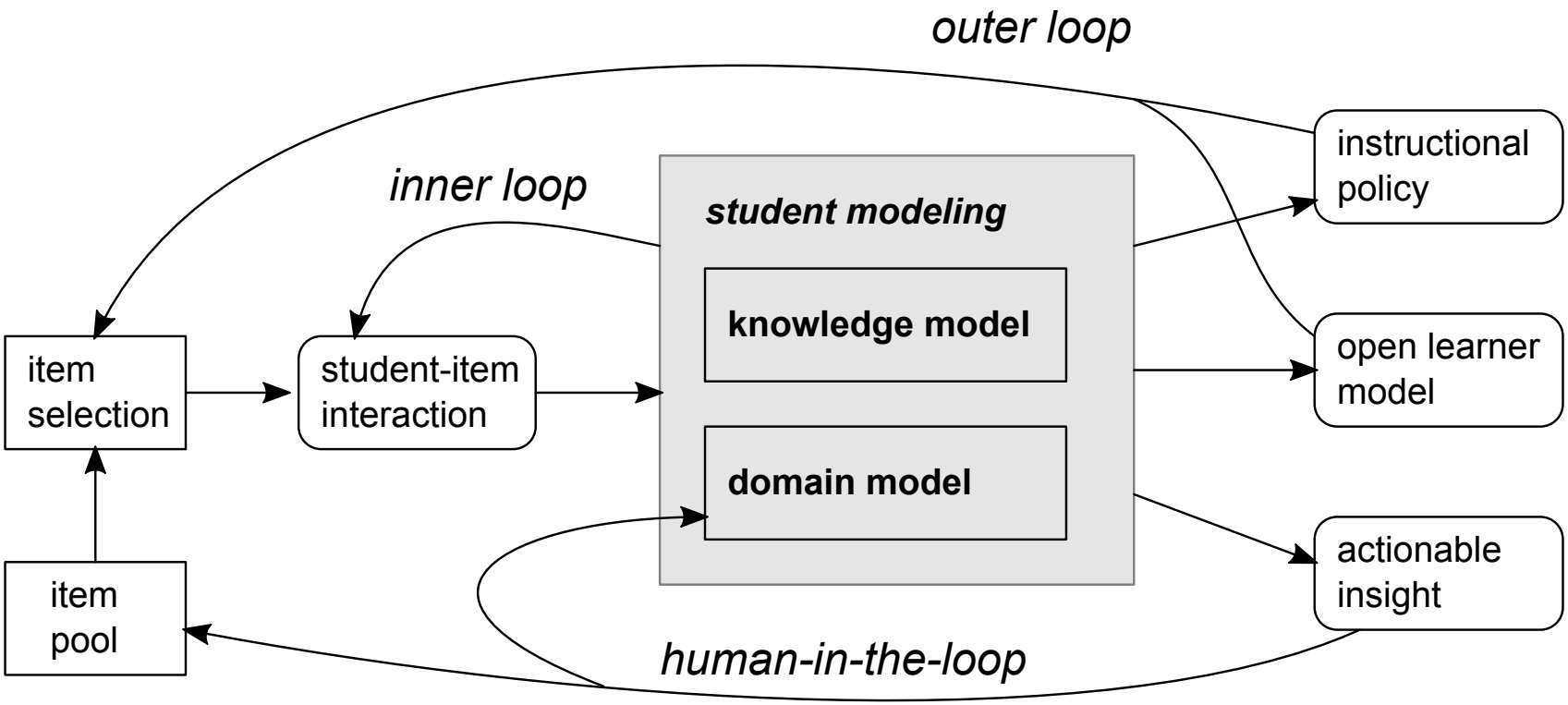
Student modeling



Bayesian Knowledge Tracing, Logistic Models, and Beyond: An Overview of Learner Modeling Techniques

Additive Factors Model

- family of "logistic models"
- Q-matrix
- used in many studies in last 10 years – see paper for overview

Q-matrix

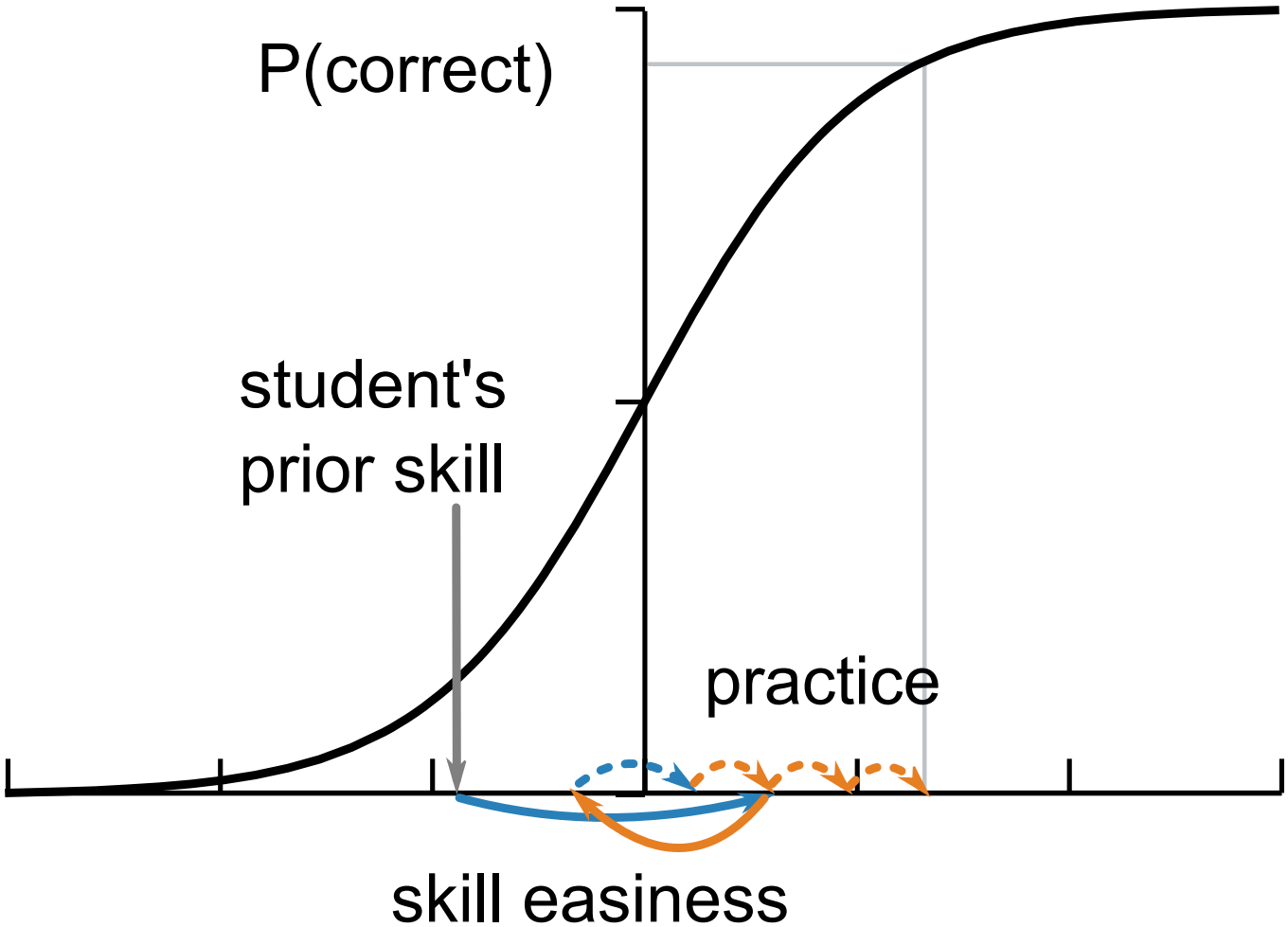
	$-$	$+$	$\times$	$()$
$10 + 3 \times 2$	0	1	1	0
$(7 - 4) \times 3$	1	0	1	1
$2 + (3 + 5)$	0	1	0	1
$8 - (6 + 2)$	1	1	0	1
$5 - 2 \times 6$	1	0	1	0

Additive Factors Model

$$P(Y_{ij}|\alpha,\beta,\gamma) = \sigma\left(\alpha_i + \sum_{k=1}^{K}\beta_k q_{jk} + \sum_{k=1}^{K}\gamma_k q_{jk} t_{ik}\right)$$

- i is student index, j is item index,
- Y_{ij} is the binary response of a student i on a item j,
- $\sigma(x) = 1/(1+e^{-x})$ is the standard logistic function,
- K is the number of skills, J is the number of items,
- Q is the $J \times K$ binary matrix – q_{jk} is the indicator that item j uses skill k,
- α_i is the proficiency (prior skill) of a student i,
- β_k is the easiness of skill k,
- γ_k is the learning rate for skill k,
- t_{ik} is the number of times student i has practiced skill k (opportunity count).

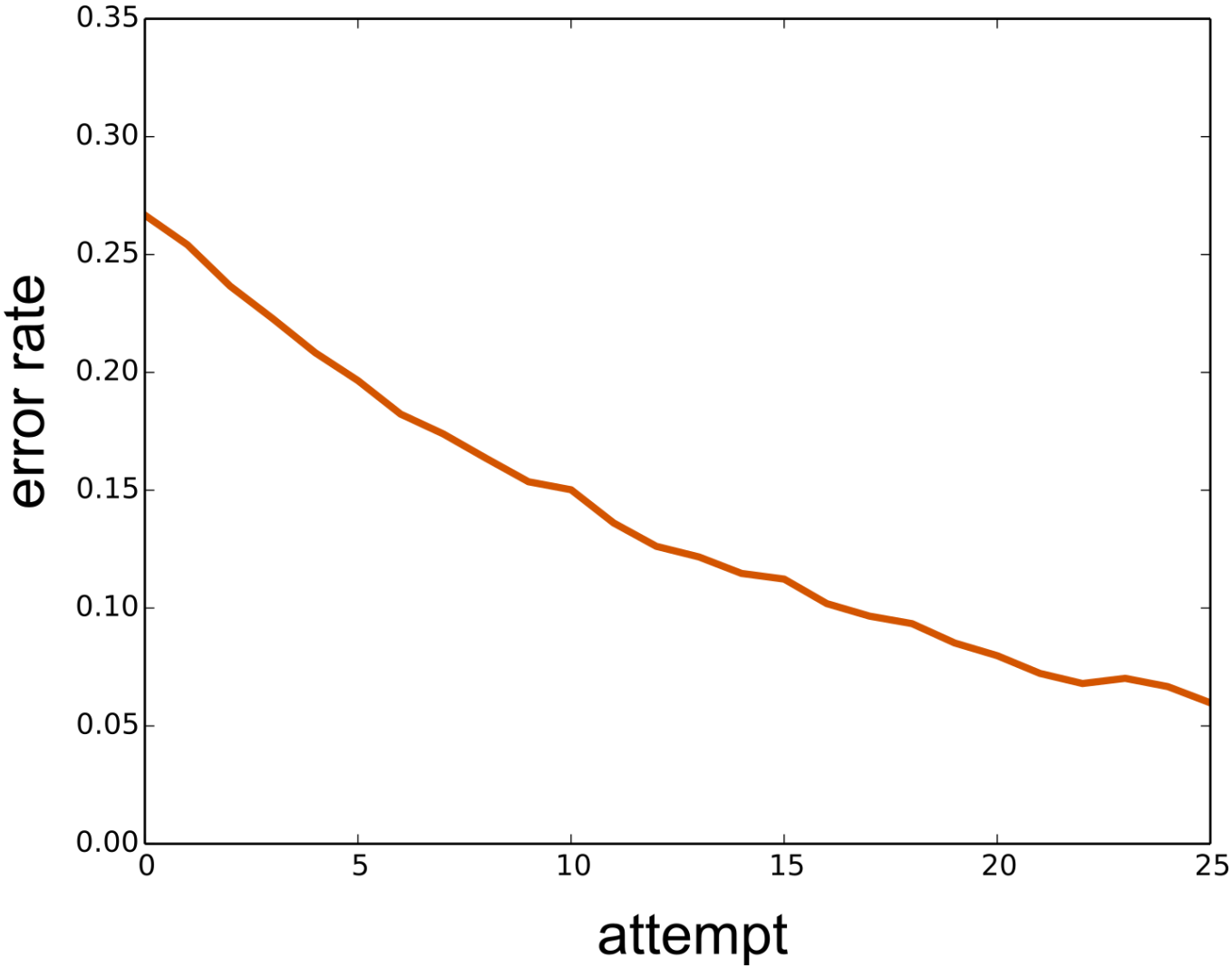
Additive Factors Model



AFM: Simplifing Assumptions

- learning is linear (on the logit scale)
- effect of practice not related to observed performance
- observed outcomes are binary (ignoring response time, common wrong answers)
- Q-matrix is binary
- compensatory model of skills
- ignores difficulty of items
- ignores biases in data (e.g., items solved in fixed order)

Learning Curves



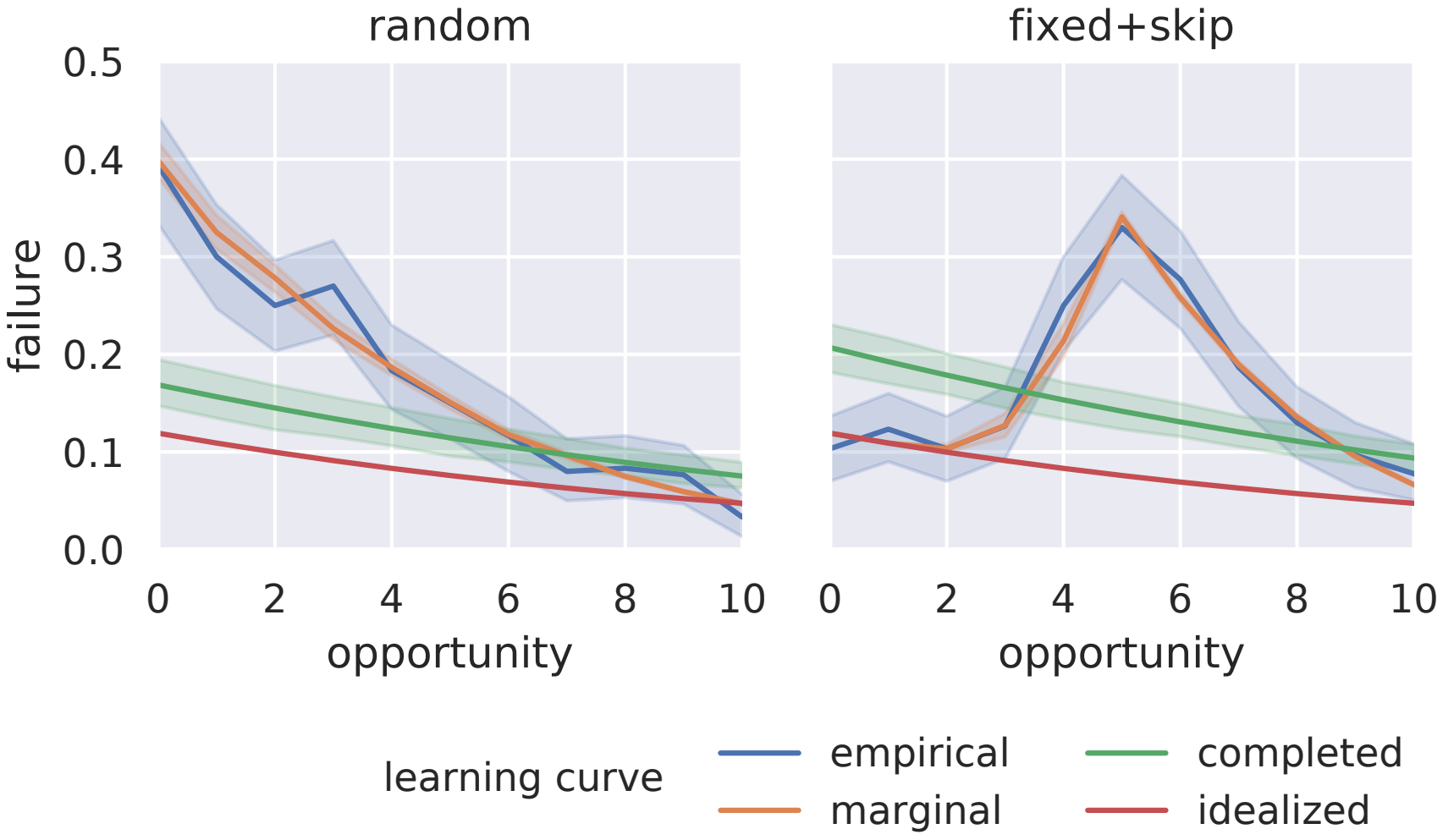
Types of Learning Curves

Type	Attempt	Opportunity	Success
empirical	observed	observed	observed
marginal	observed	observed	predicted
completed	observed	simulated	predicted
idealized	simulated	simulated	predicted

Simulation

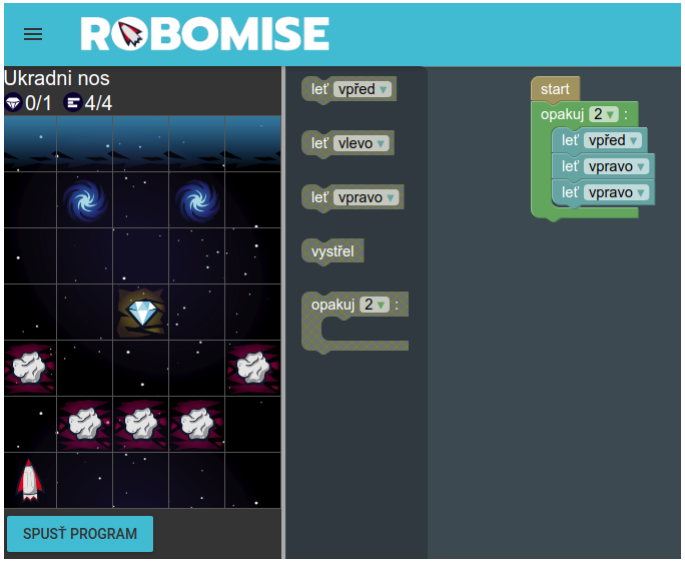
- 2 concepts
  - concept 1: easy
  - concept 2: difficult
- 15 items
- items 1-5: concept 1
- items 5-15: concept 1 & 2
- ordering: random, fixed

Learning Curves



Case Study: Programming

- block-based programming
- 85000 attempts, 5800 students, 85 items



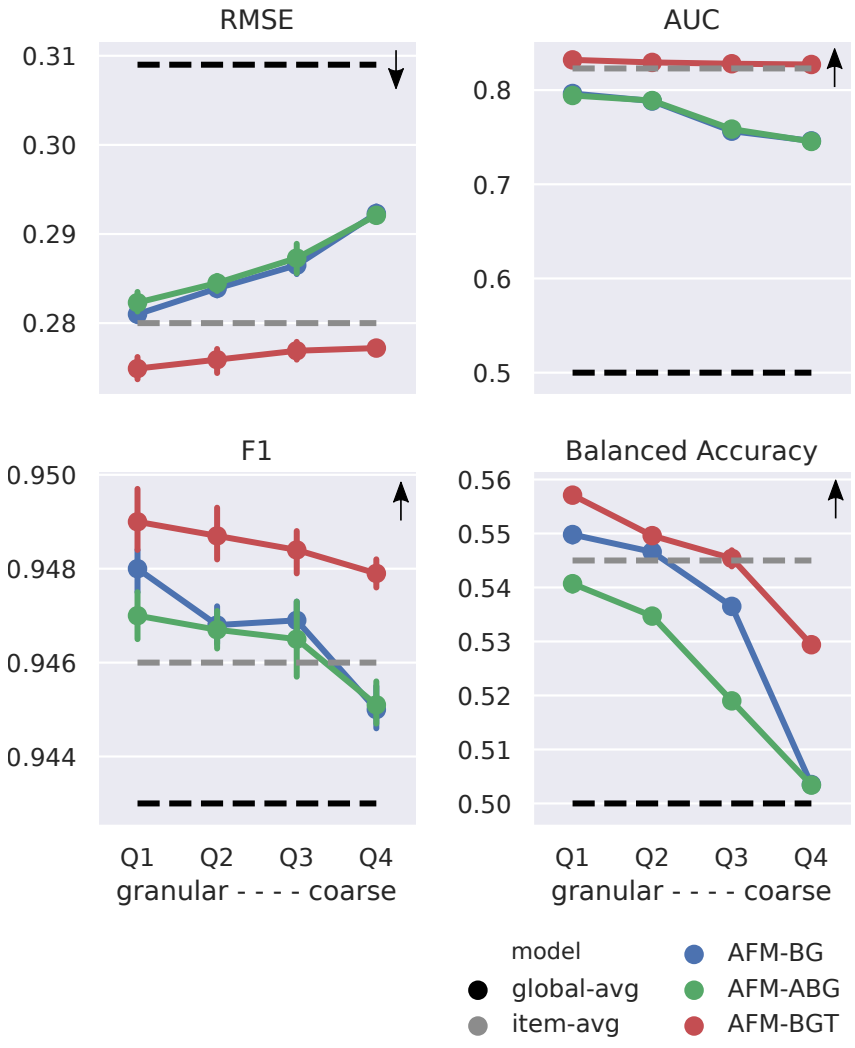
Q-matricies

Name	Concepts
Q1	*teleports*, *collectables*, *obstacles*, *destructibles*, *program length limit*, sequences, while, repeat, loop, nested-loops, if, else, test, nested control structures, comparison
Q2	*teleports*, *collectables*, *obstacles*, *destructibles*, sequences, while, repeat, nested loops, if, else
Q3	sequences, while, repeat, nested loops, if, else
Q4	sequences, loop, nested loops, test

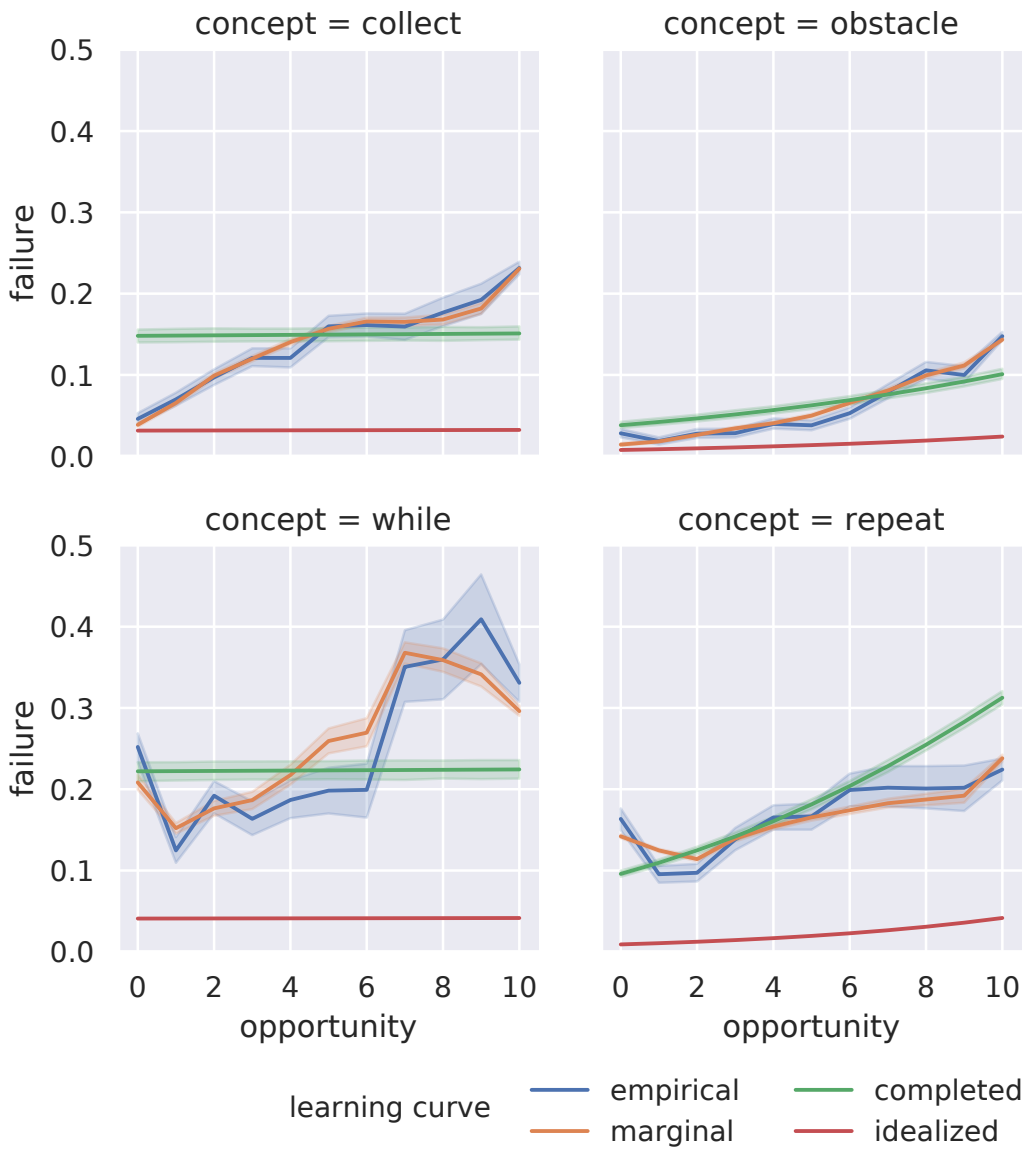
Models

- baselines: global average, item average
- AFM-BG: AFM without α parameter (student skill)
- AFM-ABG: full AFM
- AFM-BGT: AFM-BG model with item difficulties

Results: Model Comparison



Results: Learning Curves



Conclusions

- studies using AFM: more caution necessary
- AFM has many simplifying assumptions, not satisfied in practice
- possibly misleading conclusions
- basic precaution: comparison with "item average" predictor