From Prediction to Policy

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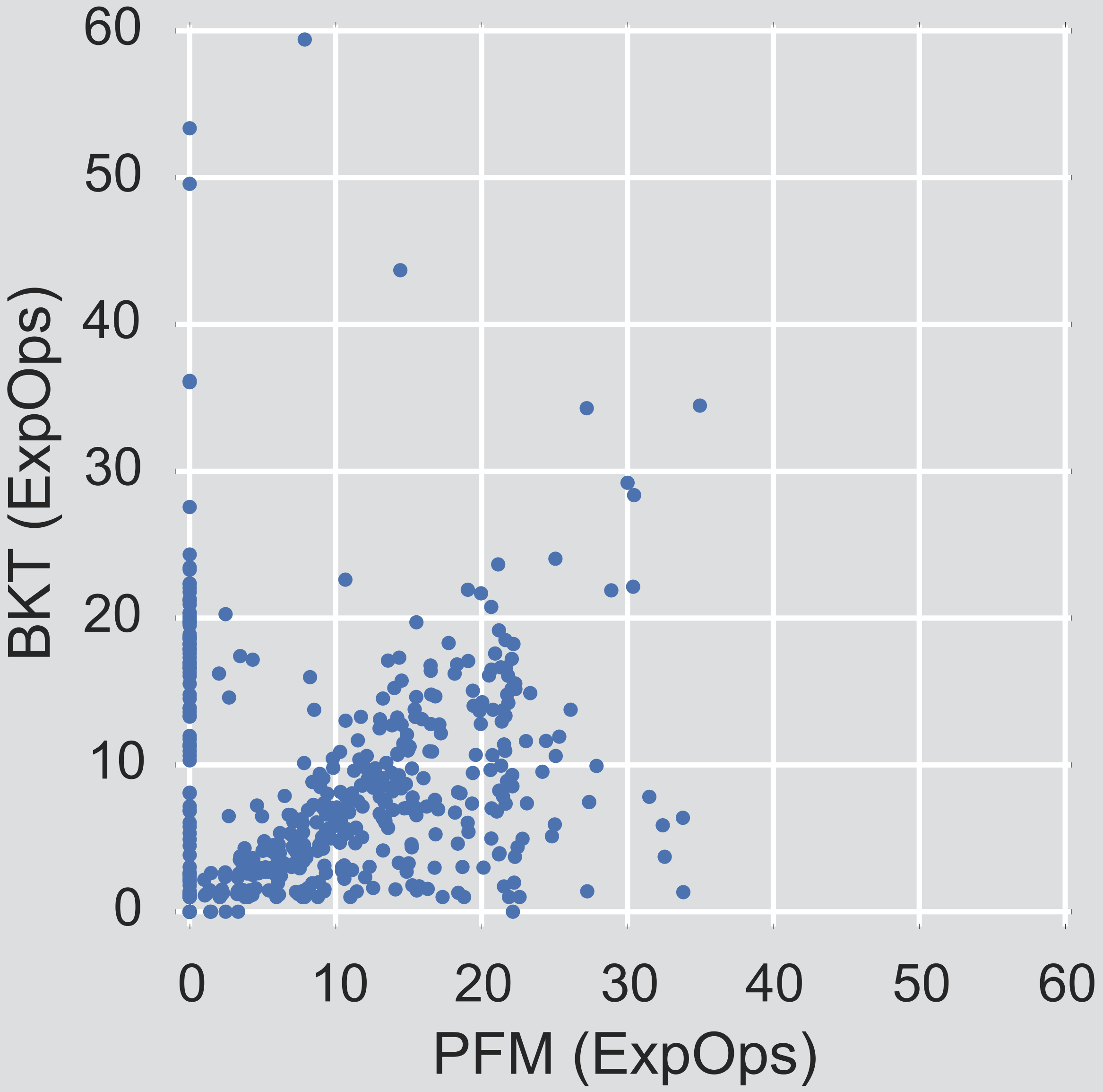
2 models

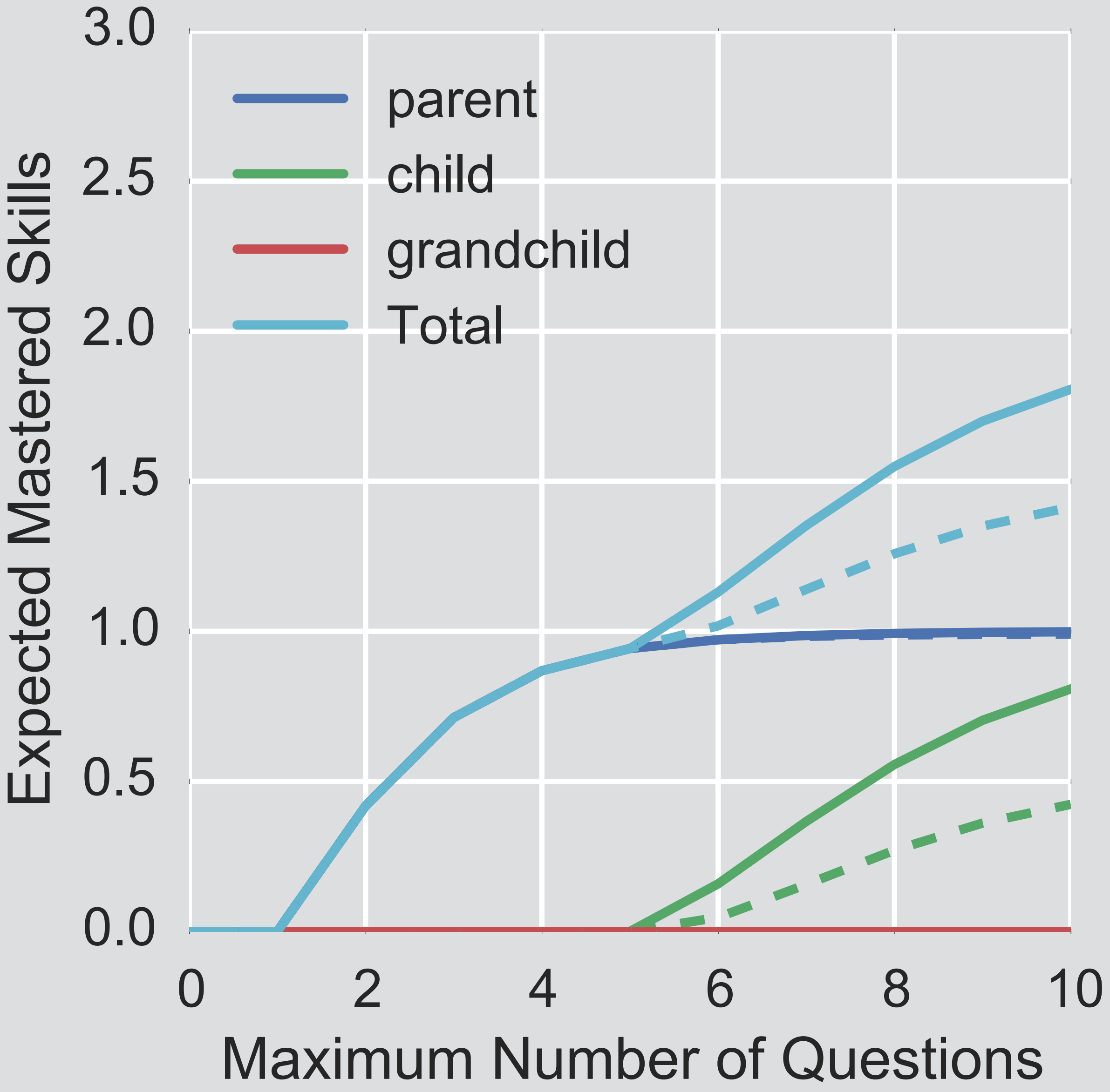
similar accuracy

different instruction



choosing multiple skills

looking ahead helps student learn more



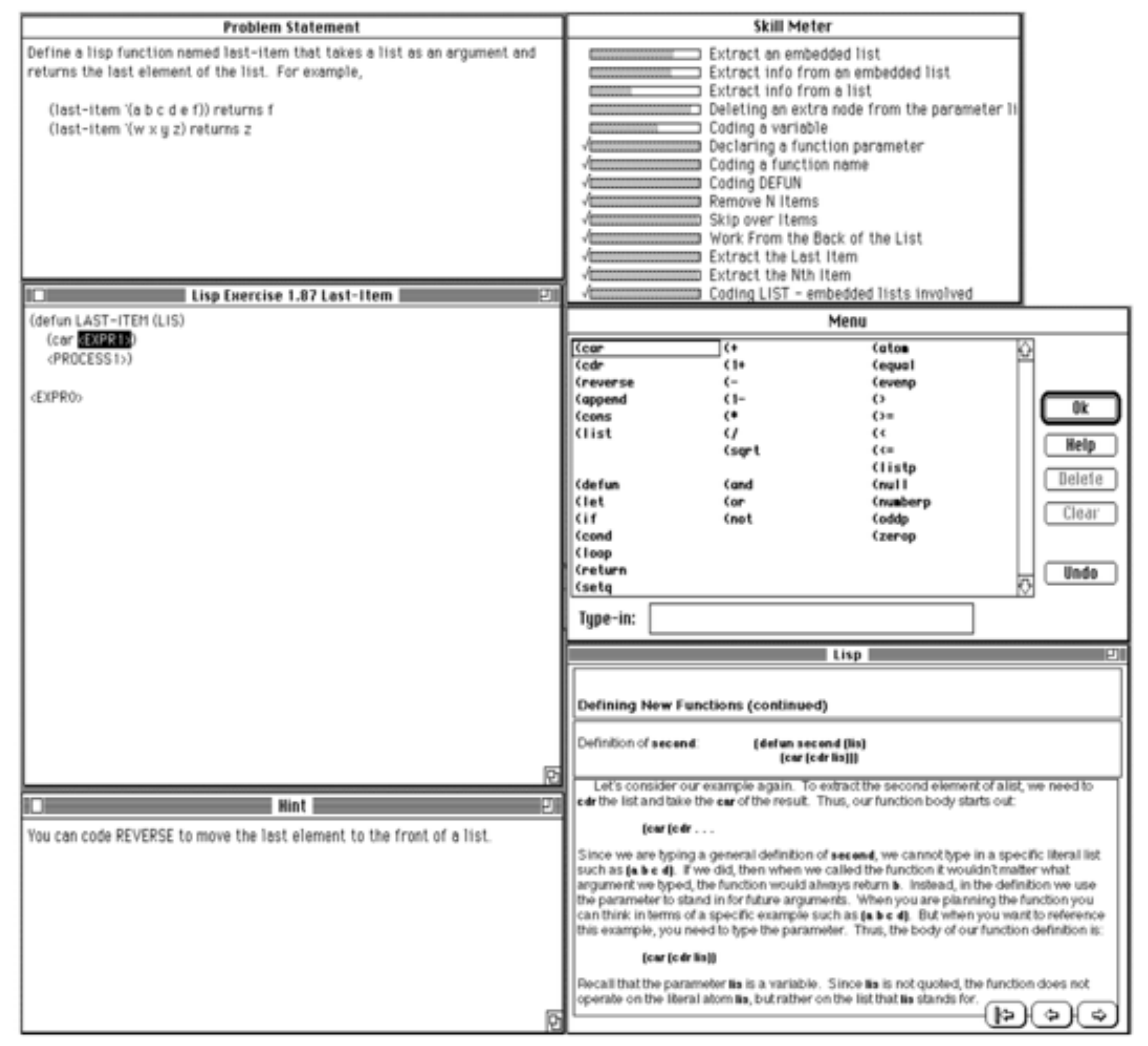
Why does this work matter?

Education Matters

Issues in Education:

1. Access
2. Quality

Solution: Intelligent Tutoring Systems (ITS)



Problem Statement

Define a lisp function named last-item that takes a list as an argument and returns the last element of the list. For example,

```
(last-item '(a b c d e f)) returns f
(last-item '(w x y z) returns z
```

Lisp Exercise 1.87 Last-Item

```
(defun LAST-ITEM (LIS)
  (car <EXPR1>)
  <PROCESS1>)

<EXPR0>
```

Hint

You can code REVERSE to move the last element to the front of a list.

Skill Meter

- Extract an embedded list
- Extract info from an embedded list
- Extract info from a list
- Deleting an extra node from the parameter li
- Coding a variable
- ✓ Declaring a function parameter
- ✓ Coding a function name
- ✓ Coding DEFUN
- ✓ Remove N Items
- ✓ Skip over Items
- ✓ Work From the Back of the List
- ✓ Extract the Last Item
- ✓ Extract the Nth Item
- ✓ Coding LIST - embedded lists involved

Defining New Functions (continued)

Definition of **second**:

```
(defun second (lis)
   (car (cdr lis)))
```

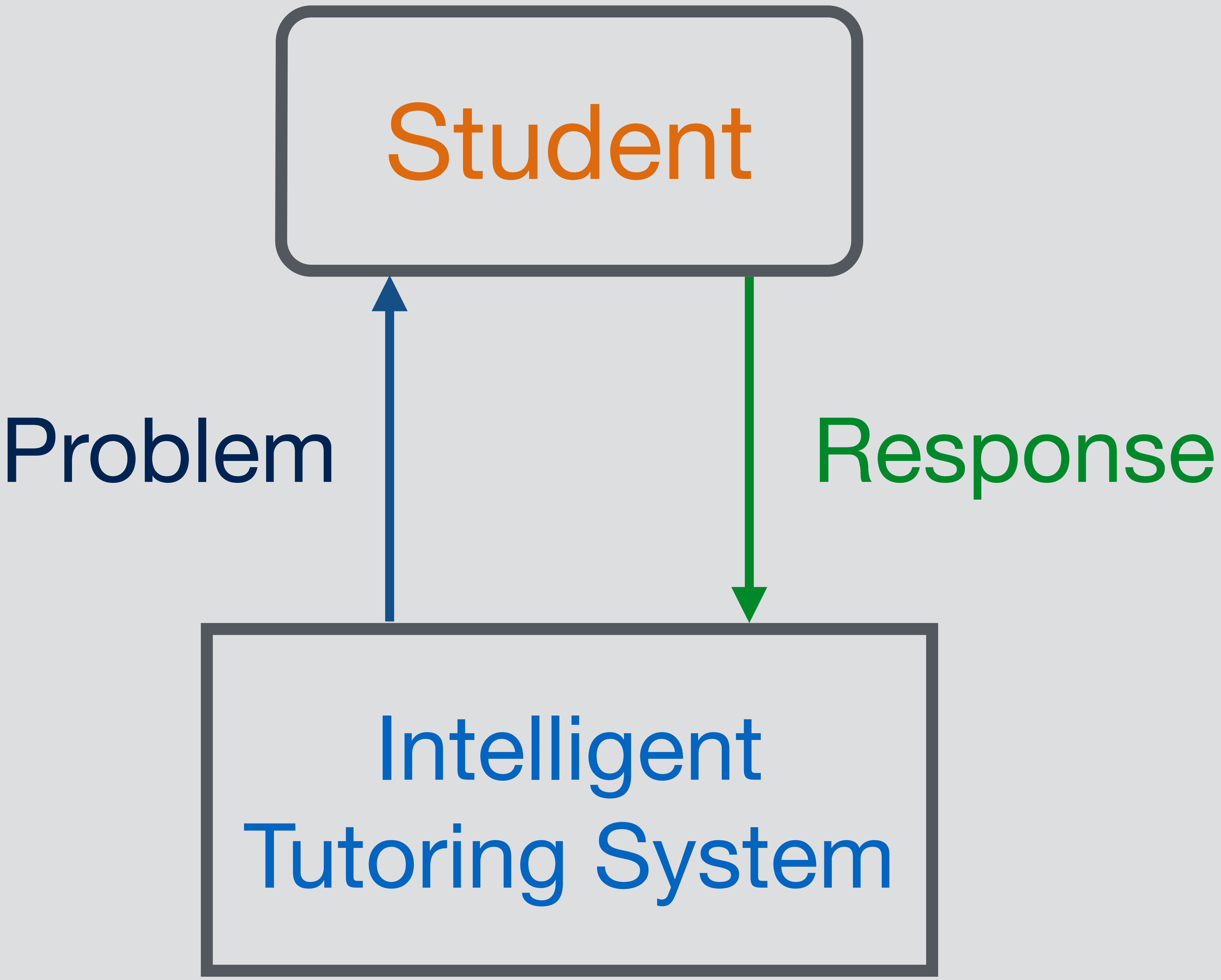
Let's consider our example again. To extract the second element of a list, we need to **cdr** the list and take the **car** of the result. Thus, our function body starts out:

(car (cdr . . .

Since we are typing a general definition of **second**, we cannot type in a specific literal list such as **(a b c d)**. If we did, then when we called the function it wouldn't matter what argument we typed, the function would always return **b**. Instead, in the definition we use the parameter to stand in for future arguments. When you are planning the function you can think in terms of a specific example such as **(a b c d)**. But when you want to reference this example, you need to type the parameter. Thus, the body of our function definition is:

(car (cdr lis))

Recall that the parameter **lis** is a variable. Since **lis** is not quoted, the function does not operate on the literal atom **lis**, but rather on the list that **lis** stands for.

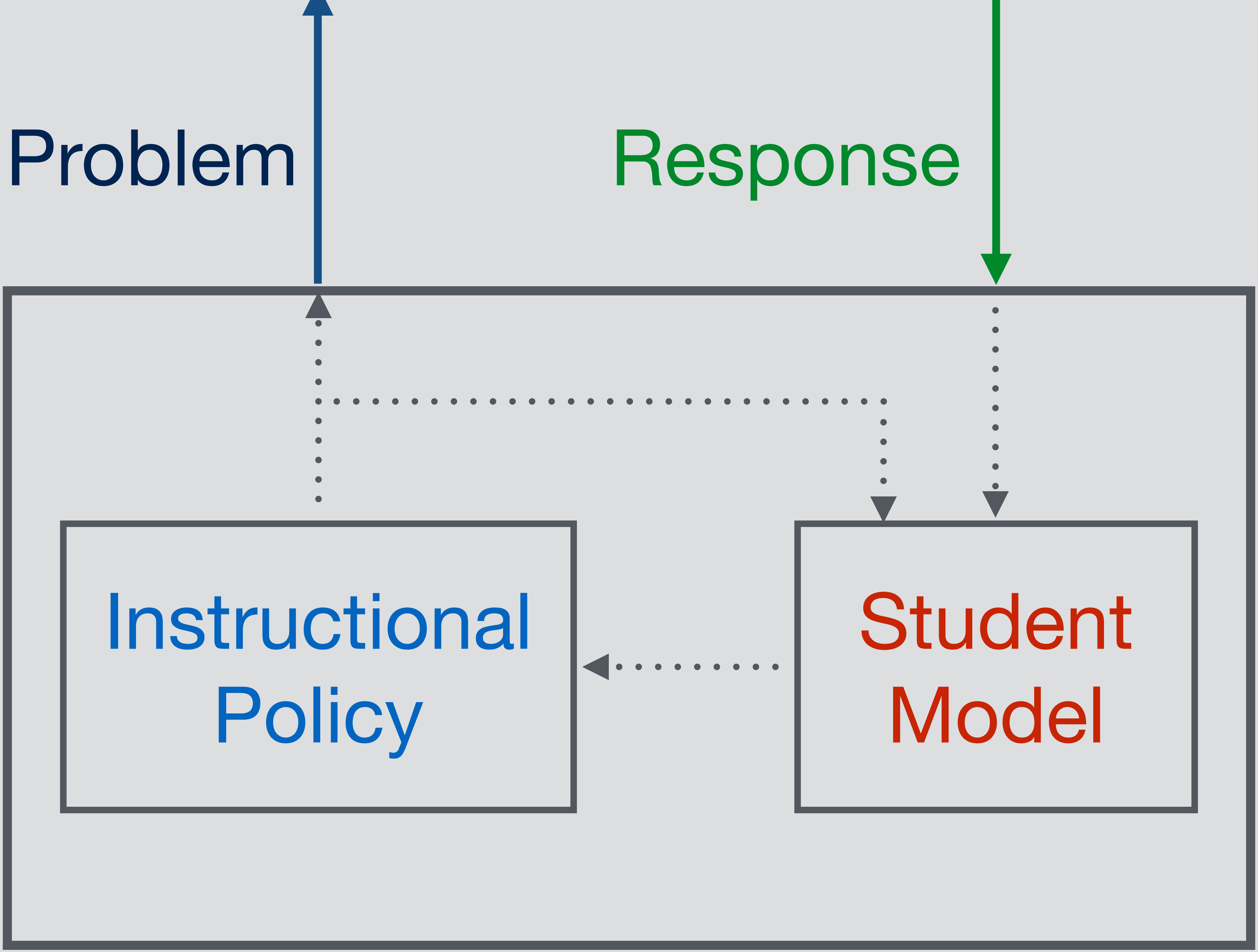


Student

Problem

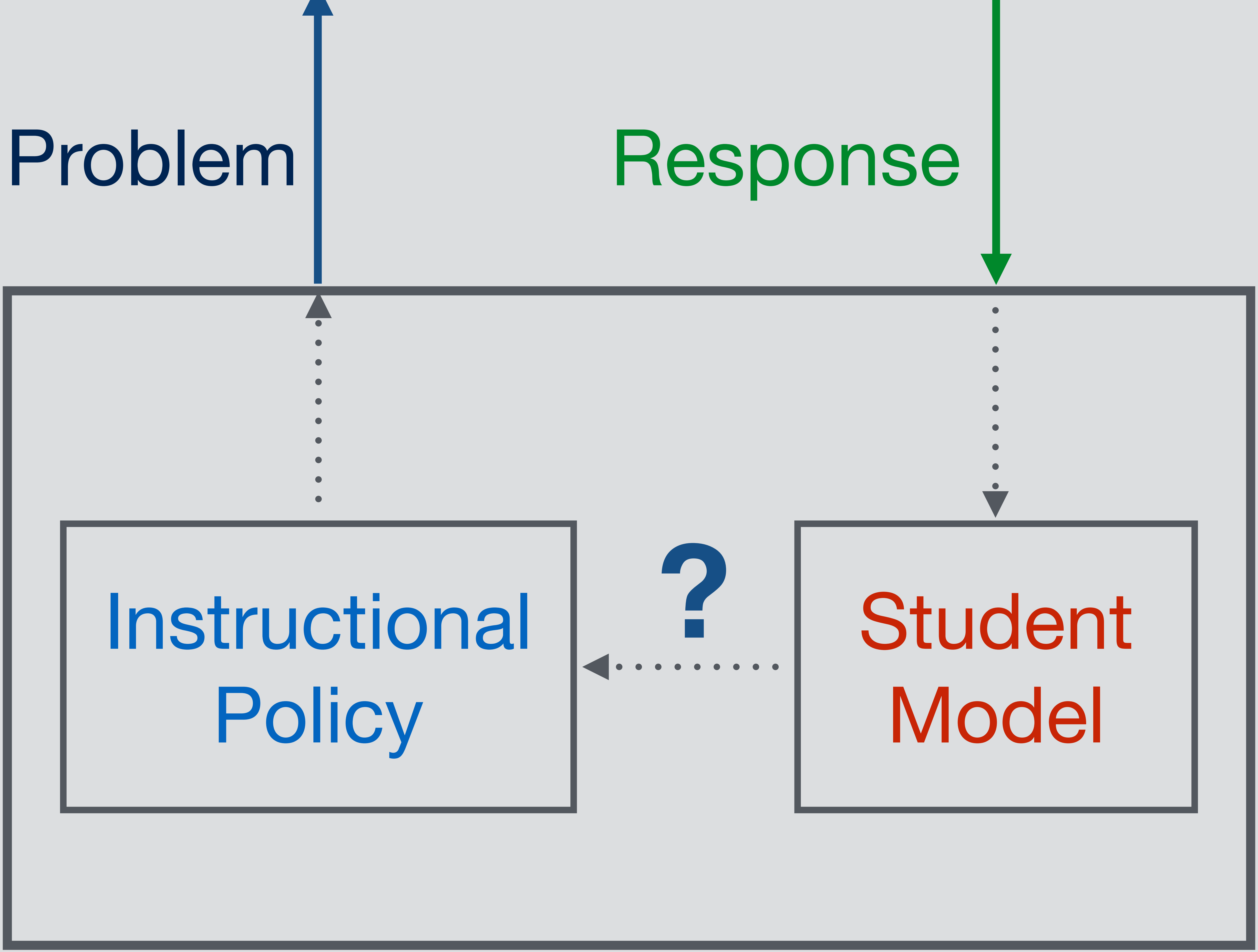
Response

Intelligent Tutoring System


Problem
Response
Instructional Policy
Student Model

Predictive Student Models

Student models are also frequently used for predicting student performance


Problem
Response
?
Instructional Policy
Student Model

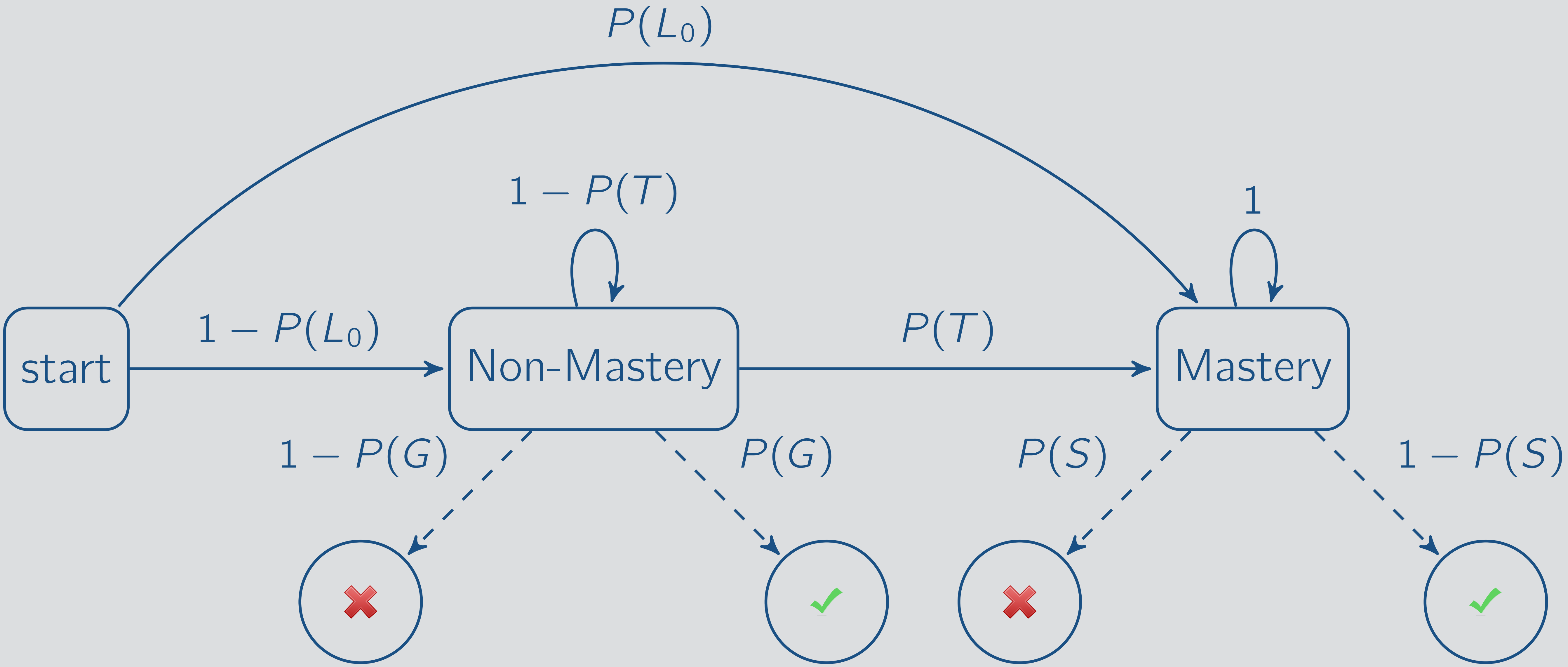
Solution: Model Agnostic Instructional Policies

Instructional policies that can use any underlying predictive student model.

Case 1:
When-To-Stop Problem

When should the system stop providing problems for the given skill to the student?

Background:
Bayesian Knowledge Tracing (BKT)



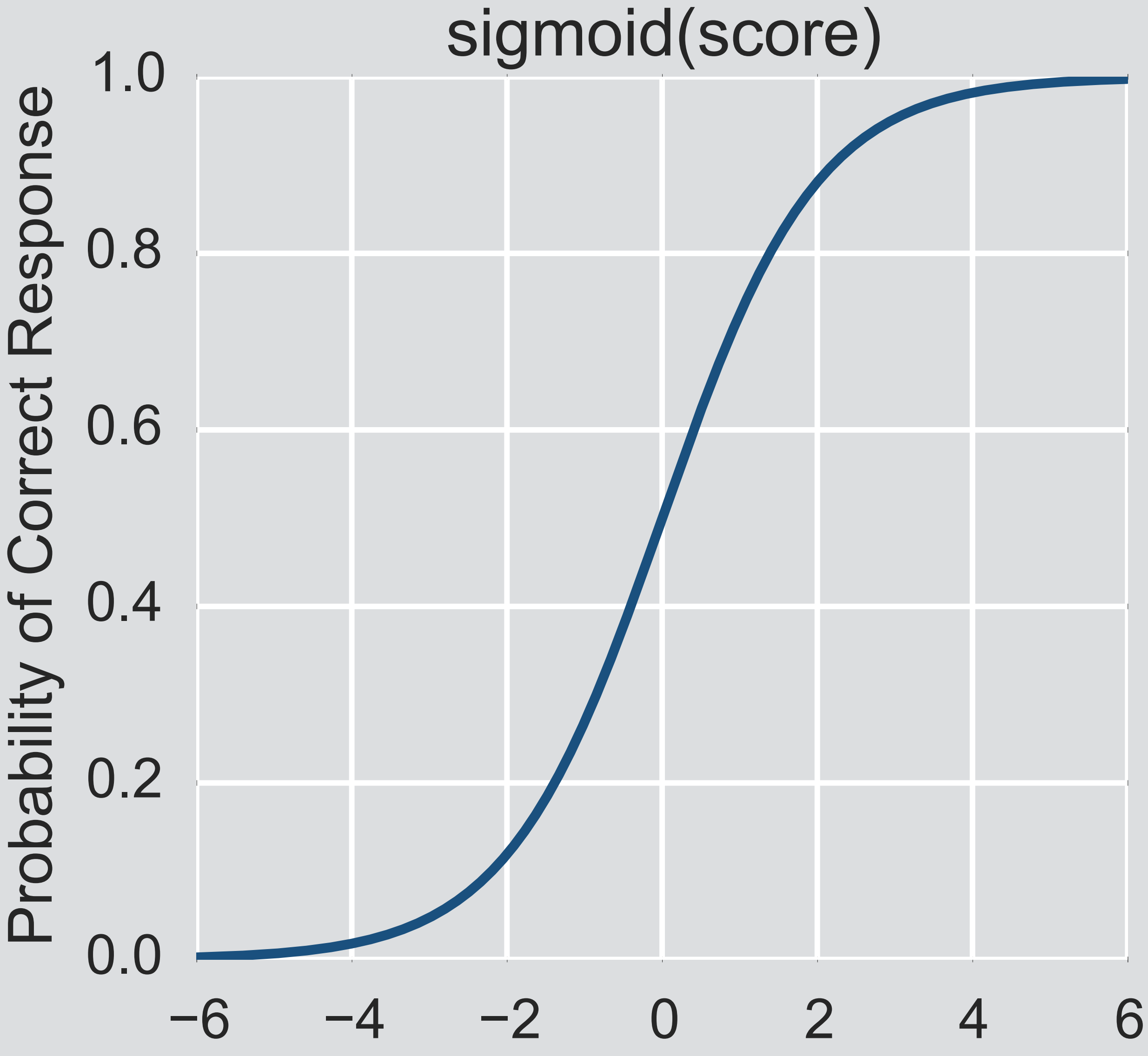
Corbett, A. T., & Anderson, J. R. (1995). Knowledge tracing: modeling the acquisition of procedural knowledge. User Modeling and User-Adapted Interaction, 4, 253–278

Background:
Performance Factors Model (PFM)

Logistic Regression Model for predicting student performance.

Features:

- Student (i)
- Skill (k)
- # Correct responses for skill (s)
- # Incorrect responses for skill (f)



score $= \alpha_i + \beta_k + \mu_k s + \rho_k f$

Pavlik Jr, Philip I., Hao Cen, and Kenneth R. Koedinger. "Performance Factors Analysis--A New Alternative to Knowledge Tracing." Online Submission (2009).

Prior Work: Mastery Threshold Policy

Stop if we are confident that the student has mastered the skill.

$$P(M) > \Delta$$

Issues with the Mastery Threshold Policy

1. Requires student model with concept of mastery.

2. Will not stop if student cannot progress with given instruction (wheel-spinning).

Beck, Joseph E., and Yue Gong. "Wheel-spinning: Students who fail to master a skill." Artificial Intelligence in Education. Springer Berlin Heidelberg, 2013.

New Policy: Predictive Similarity Policy

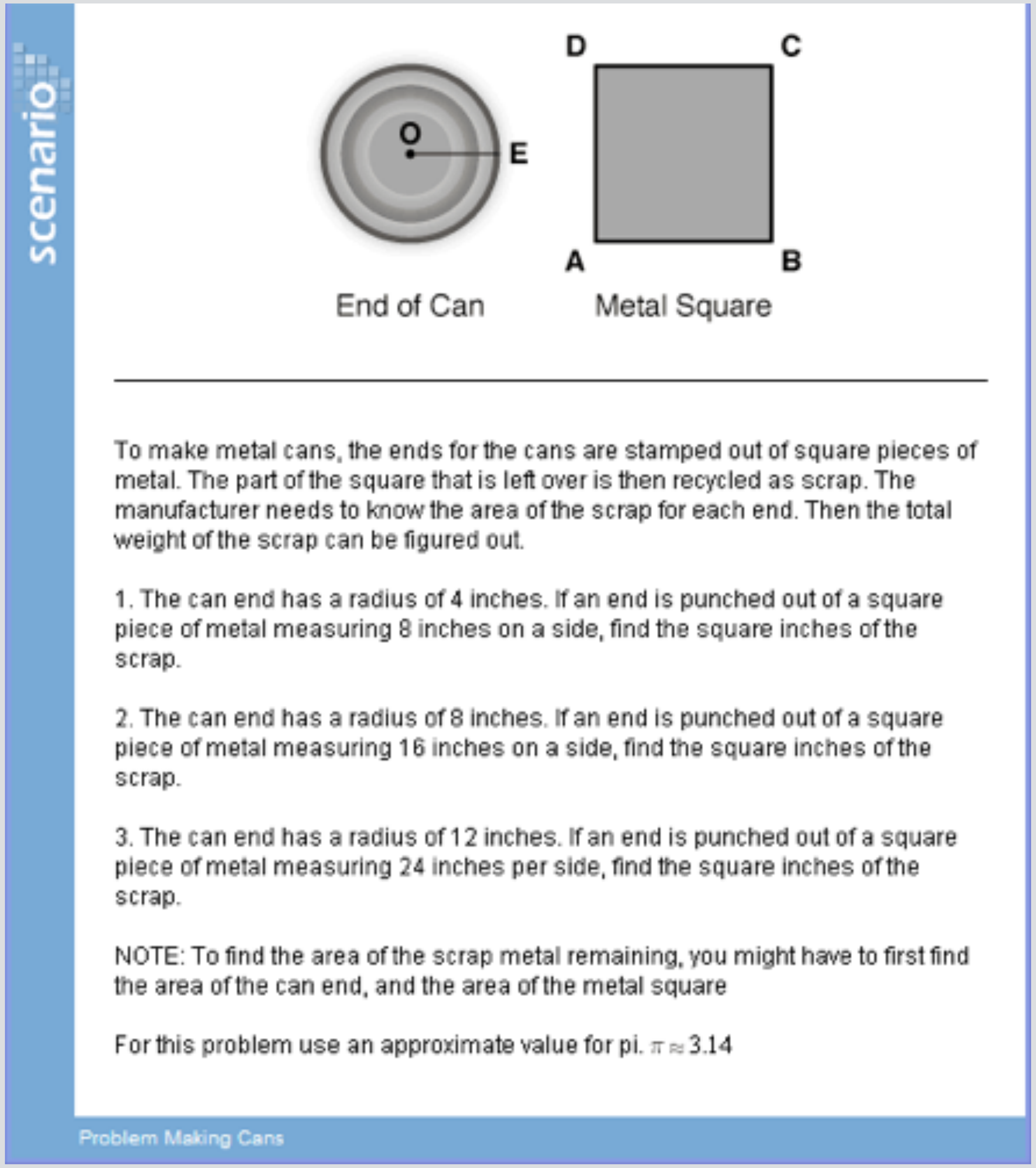
Stop if we are confident that our prediction of the student's performance will not change much.

$$P\left(\left|P(C_{t+1}) - P(C_t)\right| < \epsilon\right) > \delta$$

Data: Algebra I

> 3000 students

505 skills



To make metal cans, the ends for the cans are stamped out of square pieces of metal. The part of the square that is left over is then recycled as scrap. The manufacturer needs to know the area of the scrap for each end. Then the total weight of the scrap can be figured out.

1. The can end has a radius of 4 inches. If an end is punched out of a square piece of metal measuring 8 inches on a side, find the square inches of the scrap.

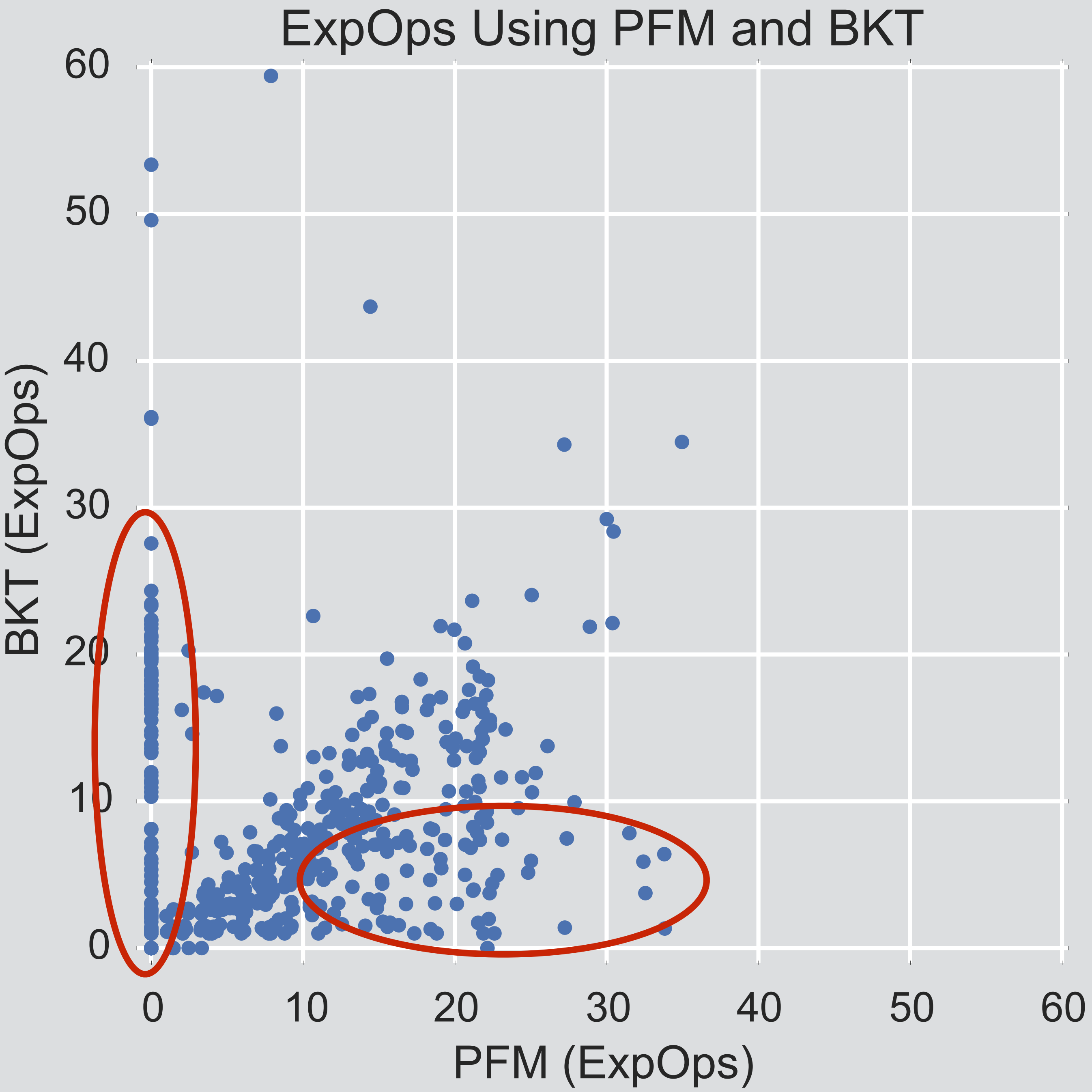
2. The can end has a radius of 8 inches. If an end is punched out of a square piece of metal measuring 16 inches on a side, find the square inches of the scrap.

3. The can end has a radius of 12 inches. If an end is punched out of a square piece of metal measuring 24 inches per side, find the square inches of the scrap.

NOTE: To find the area of the scrap metal remaining, you might have to first find the area of the can end, and the area of the metal square

For this problem use an approximate value for pi. $\pi \approx 3.14$

How much does the underlying student model affect the Predictive Similarity Policy?



Case 2:
Skill-Choice Problem

Given T available questions, what skill should the next problem teach?

Independent Skills

French Grammar

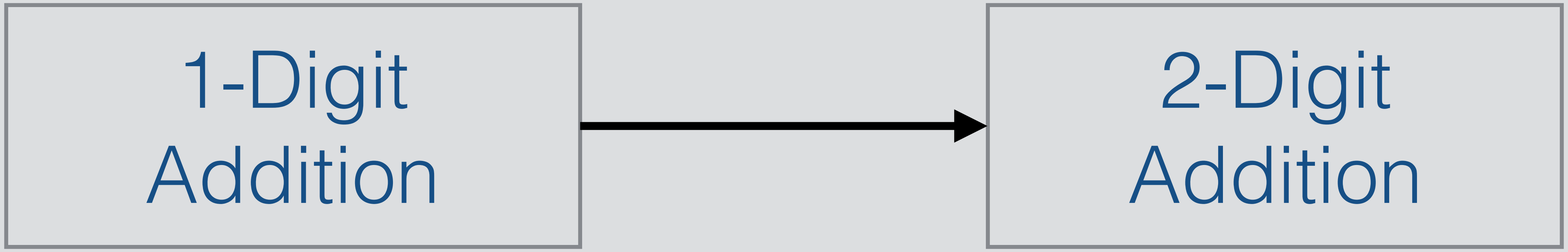
Fraction Addition

être

je suis
tu es
il / elle est
nous sommes
vous êtes
ils / elles sont

$$\frac{2}{3} + \frac{1}{4} = \frac{11}{12}$$

Dependent Skills



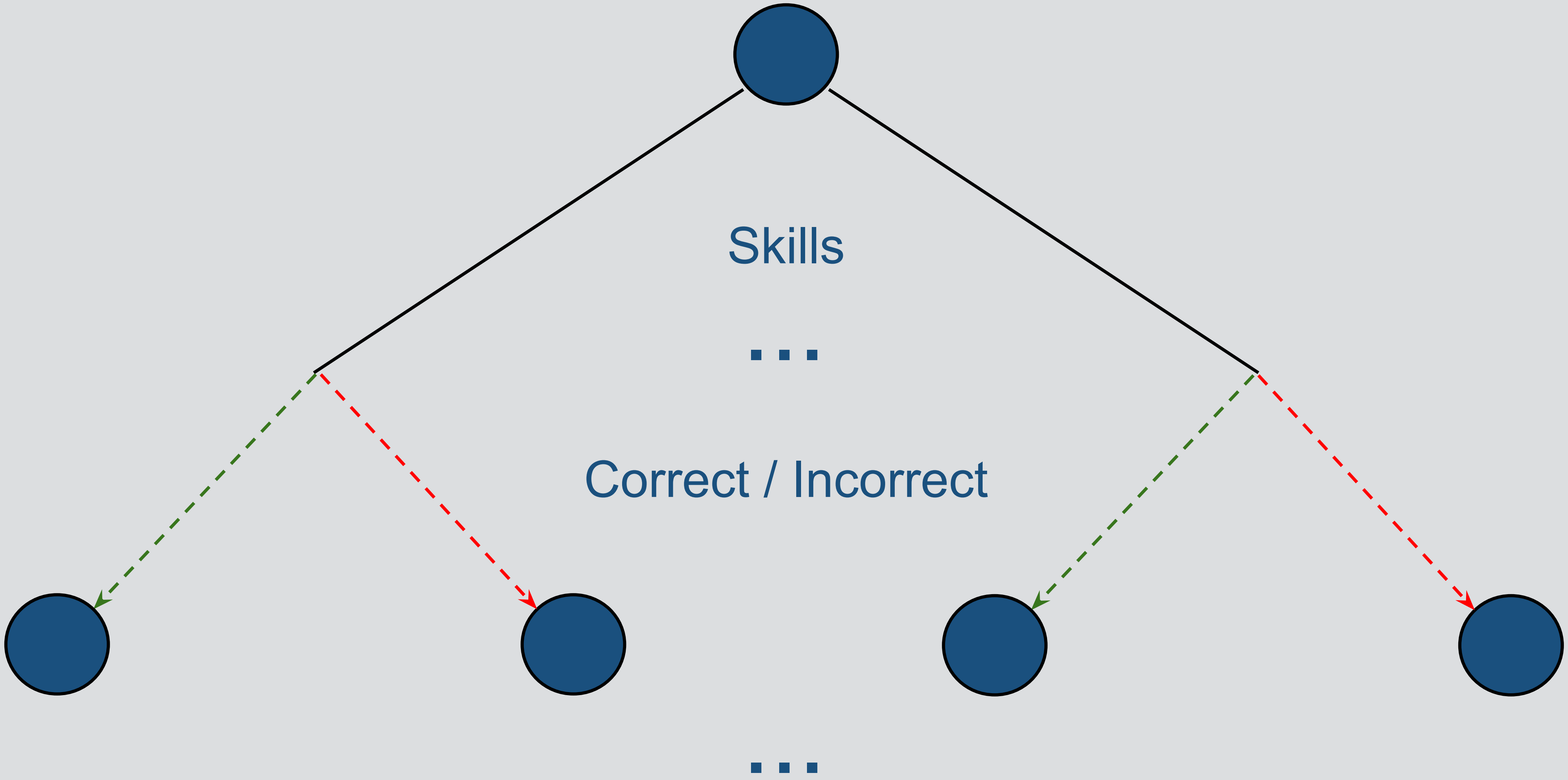
$4 + 3 = 7$

$46 + 17 = 63$

Problem

Pick the skill to maximize the final number mastered skills

What skill to teach?



Maximization

Skills

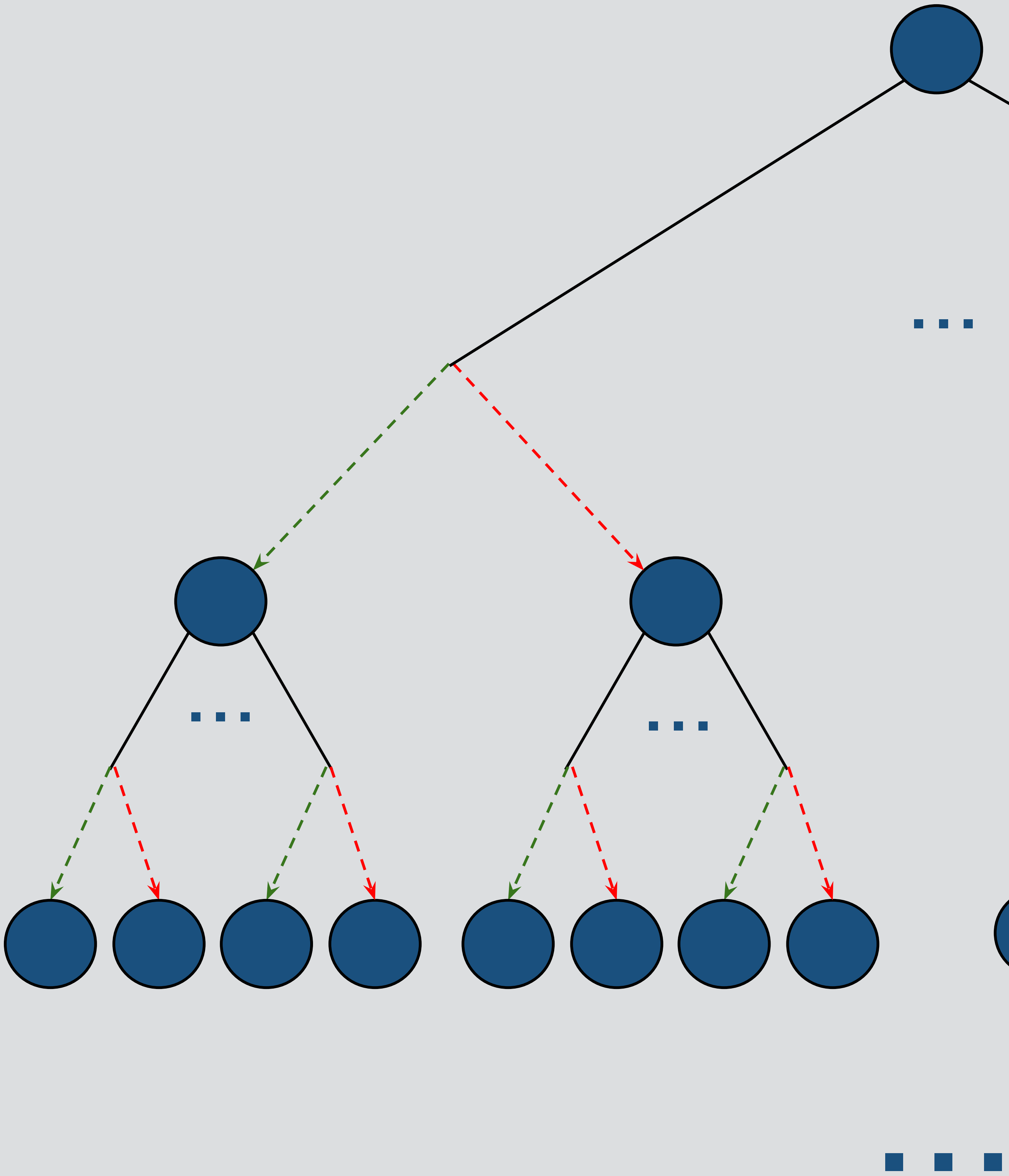
...

Expectation

Correct / Incorrect

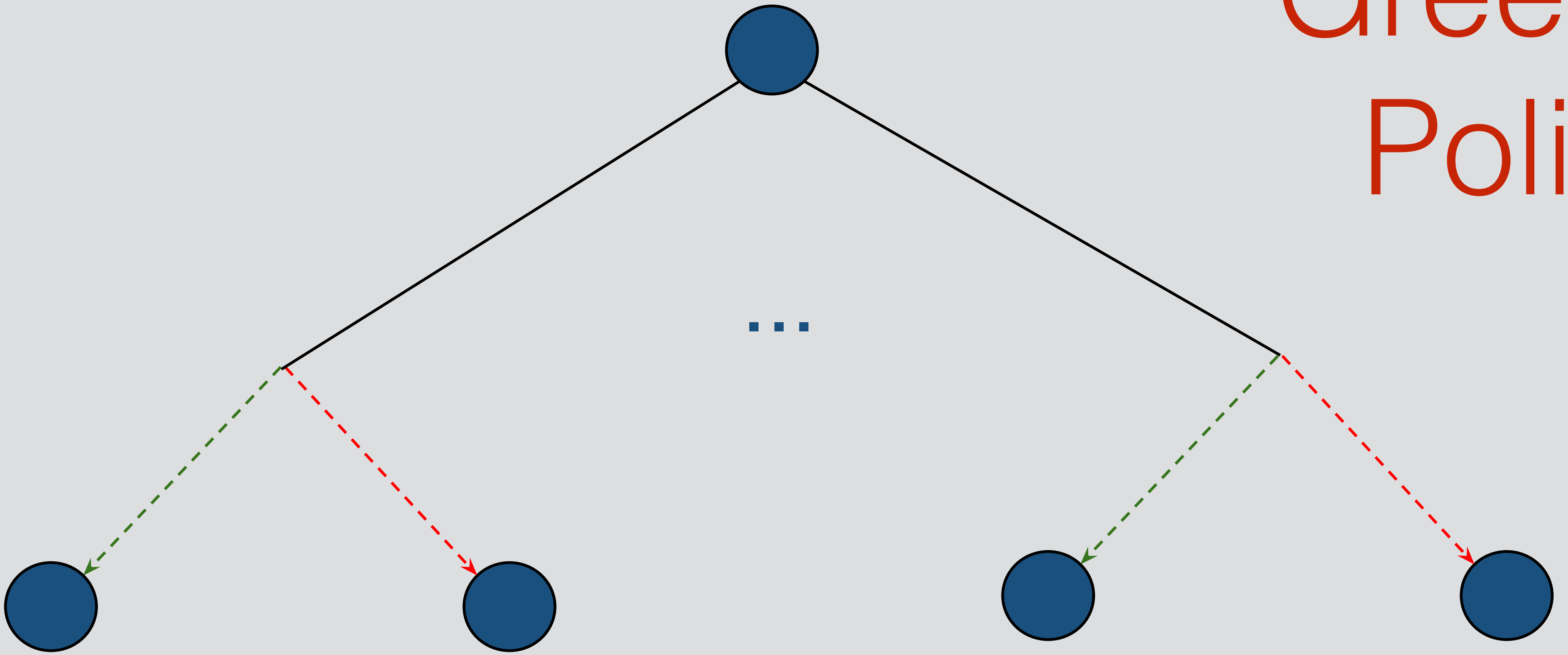
...

Full Horizon Policy



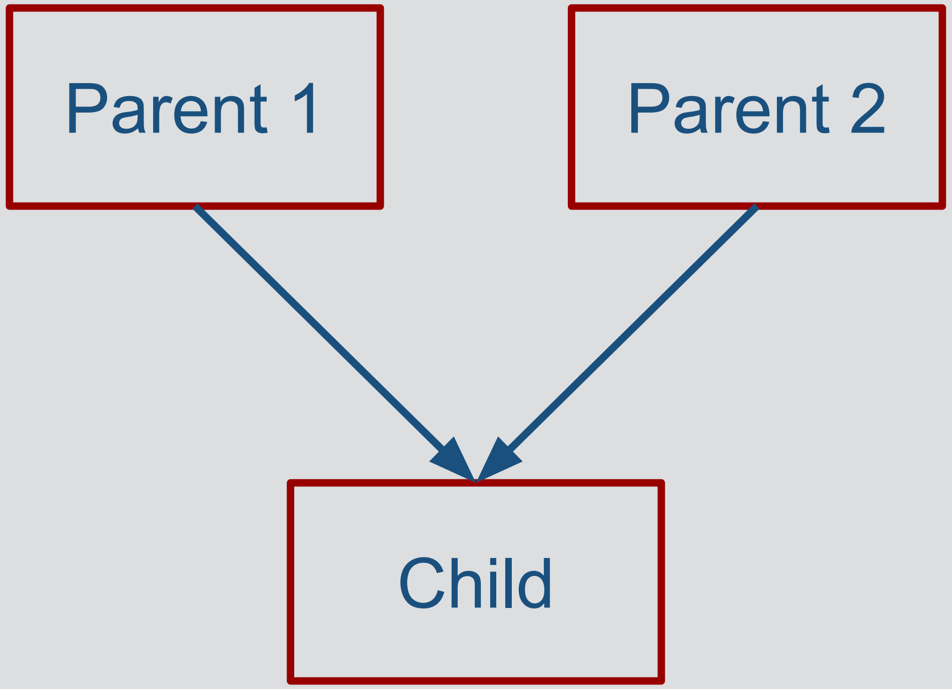
$O\left((2|K|)^T\right)$

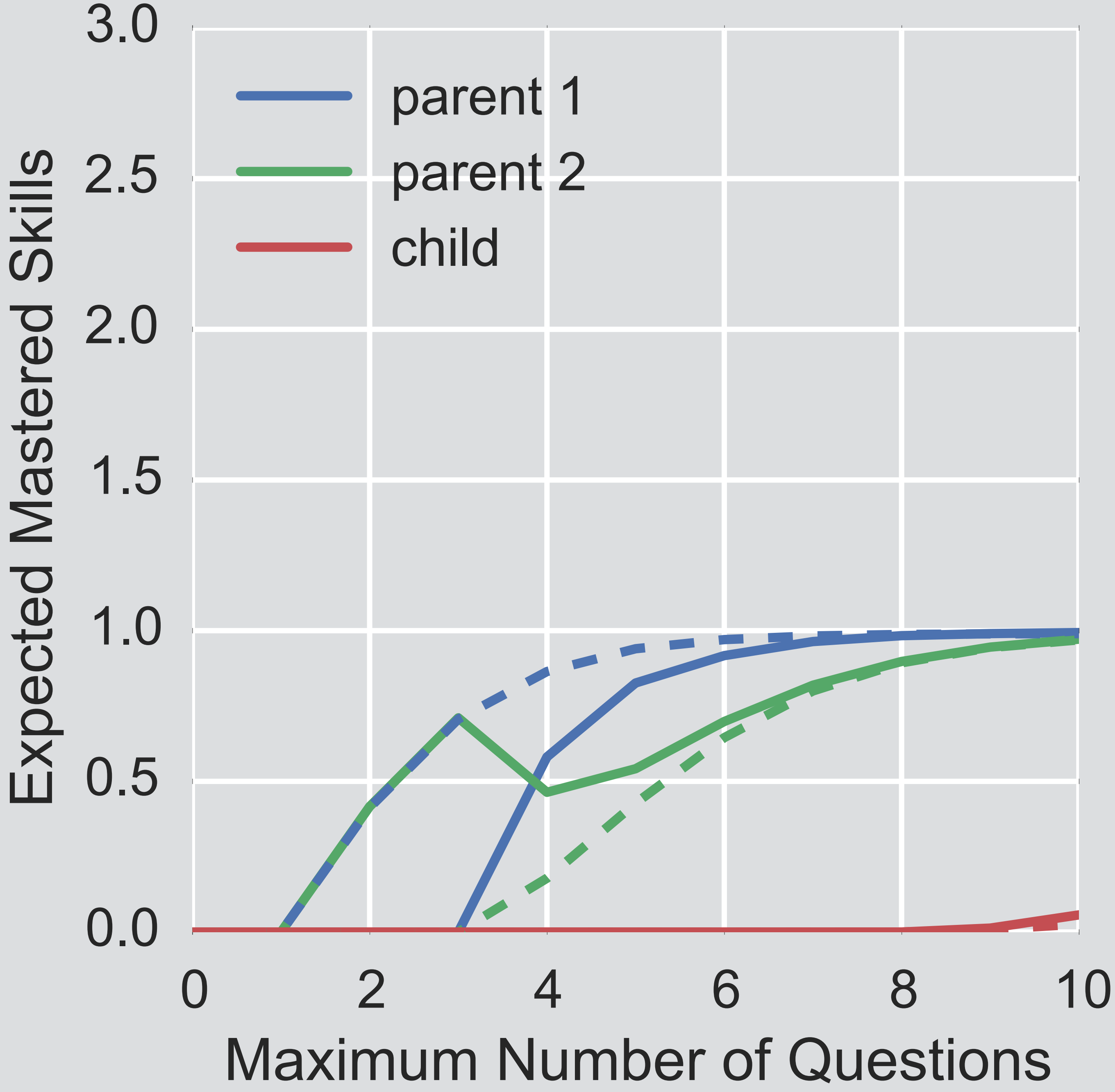
Greedy Policy



$O(2|K|)$

How does the Greedy policy compare to the Full Horizon Policy?





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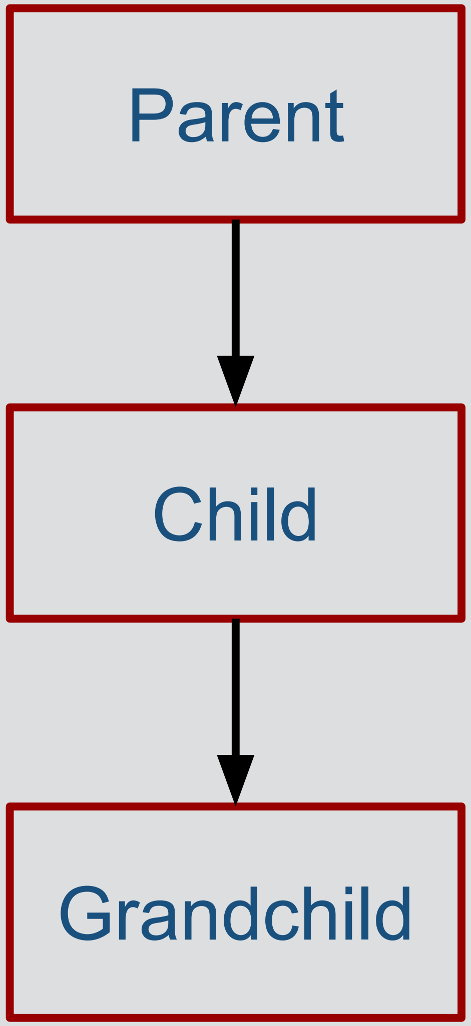
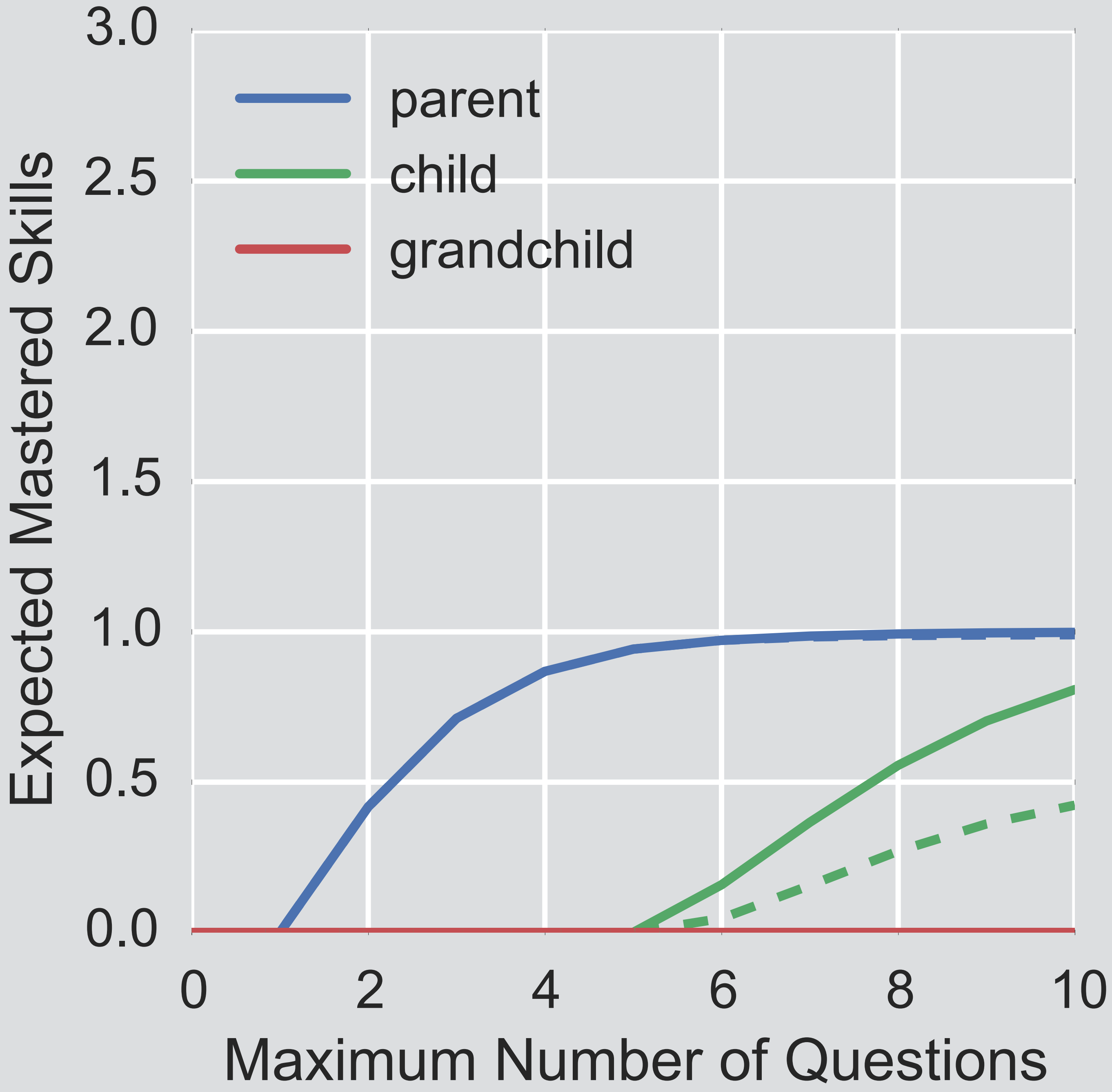
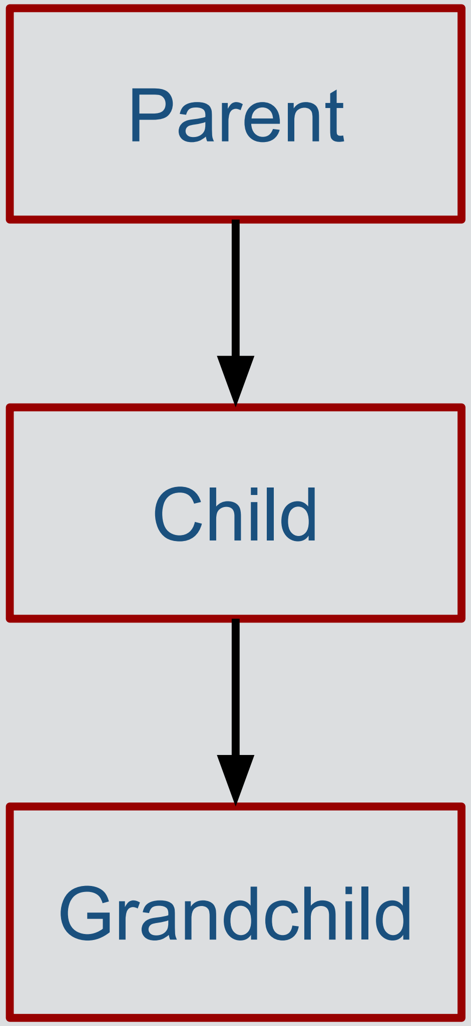
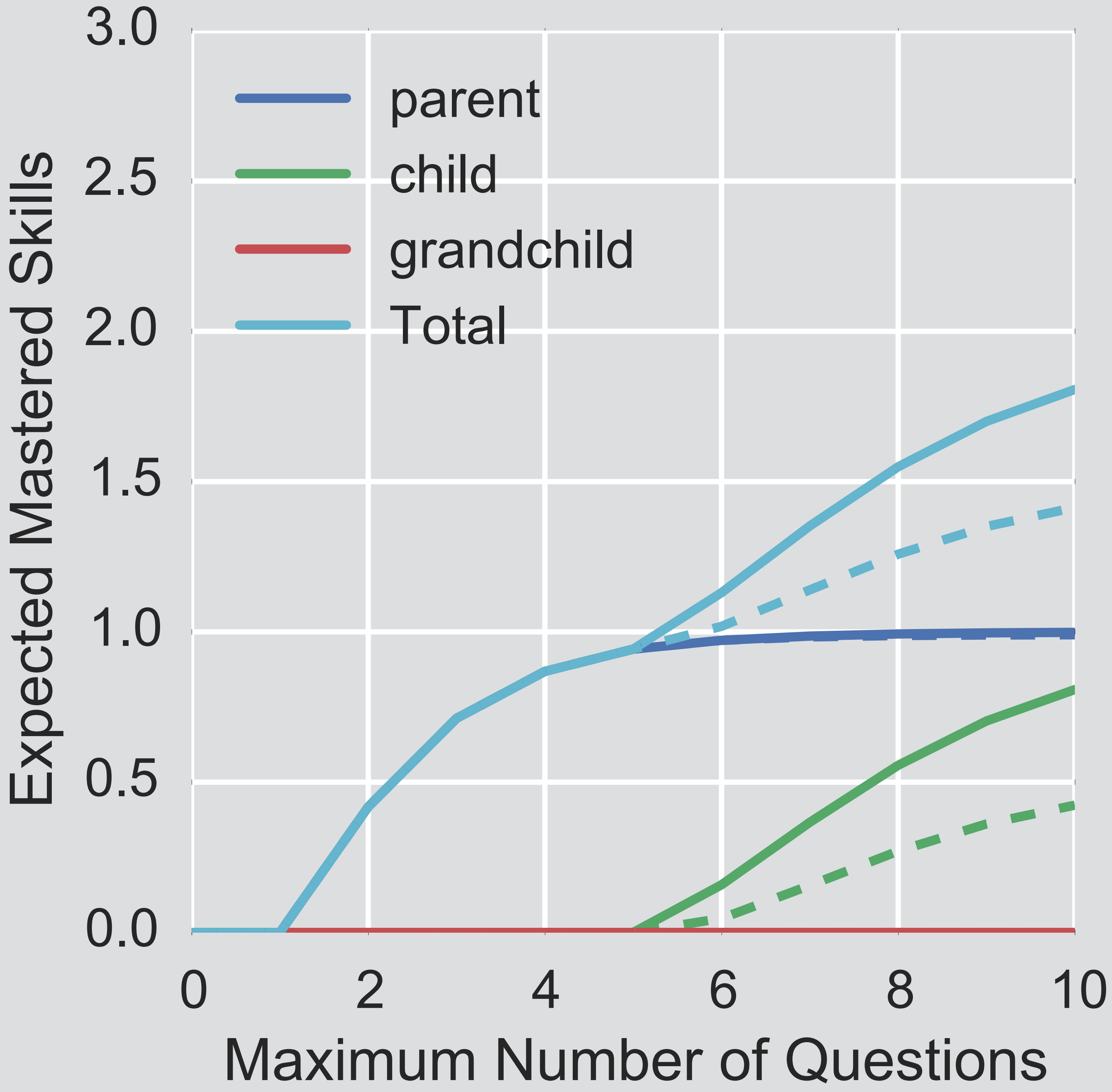




Looking ahead makes the student learn more





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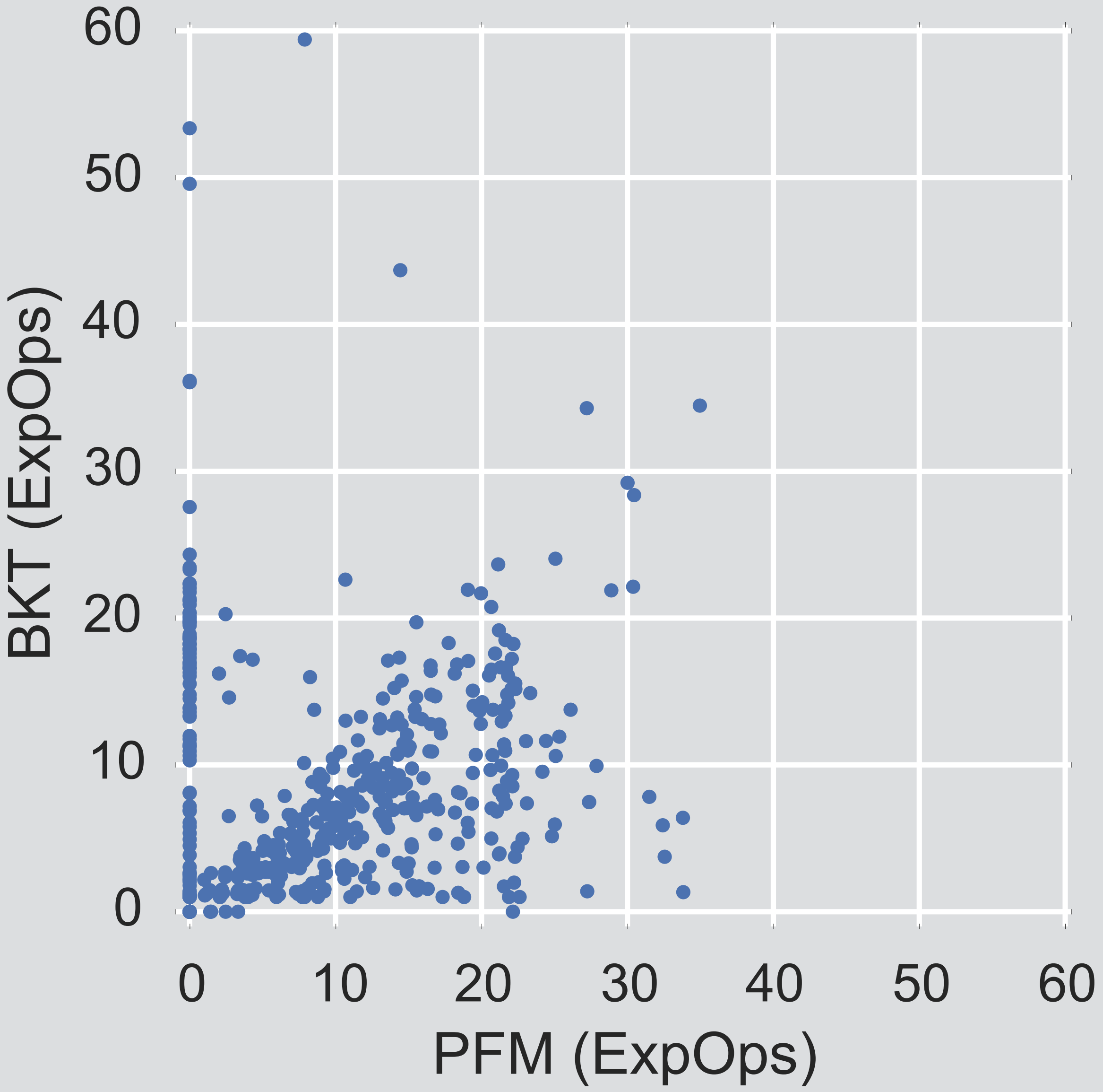

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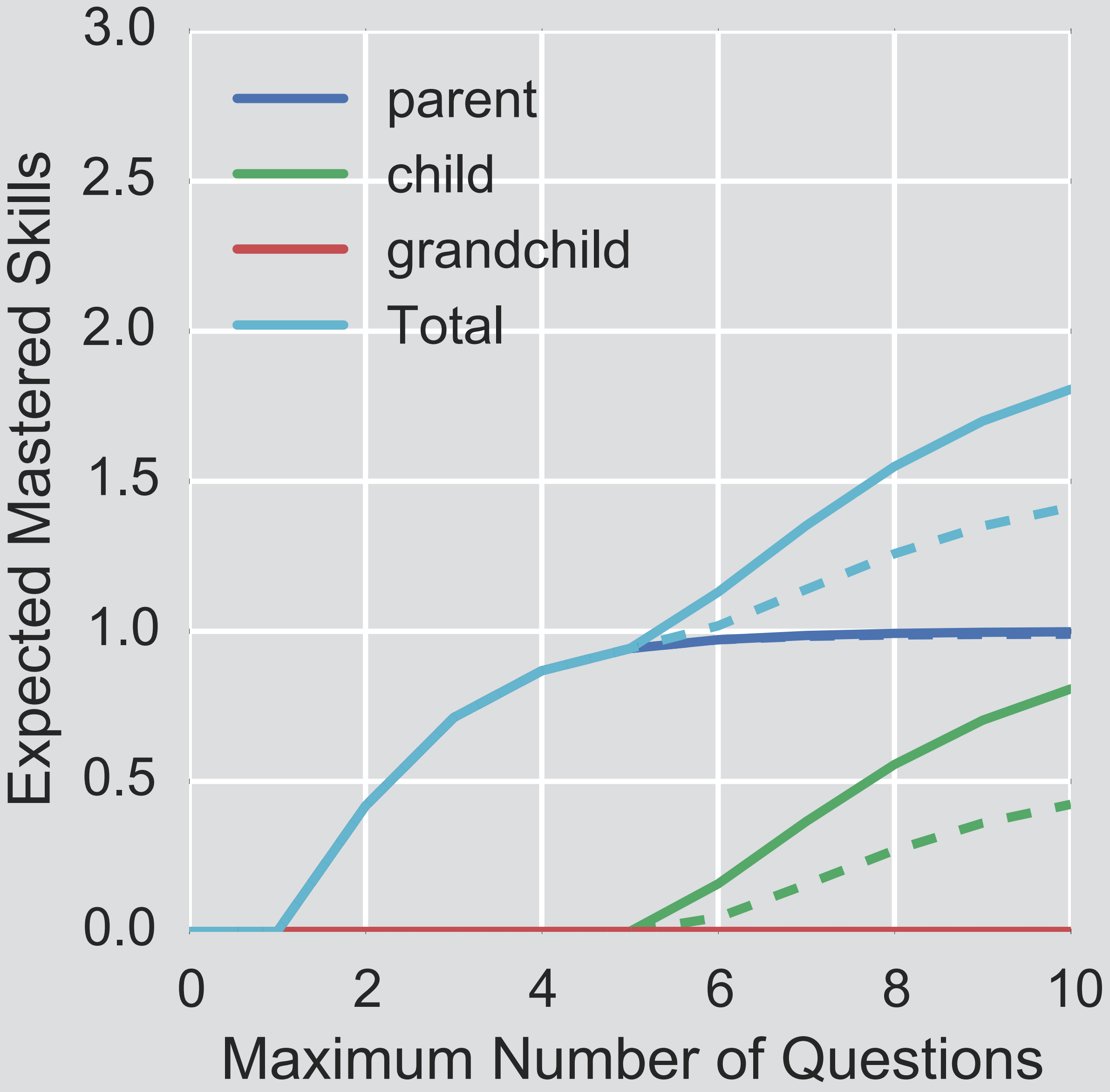

Future Work

- Multi-skill experiments with real data.
- Test more complicated skill hierarchies.
- Evaluating instructional policies.

Contributions this year

- Model agnostic when-to-stop policy.
- Windowed PFM for preventing extreme asymptotes.
- Hierarchical PFM for capturing skill hierarchies.
- Model agnostic skill-choice policies.

Questions?