A Unified Framework for Knowledge Assessment and Progression Analysis and Design

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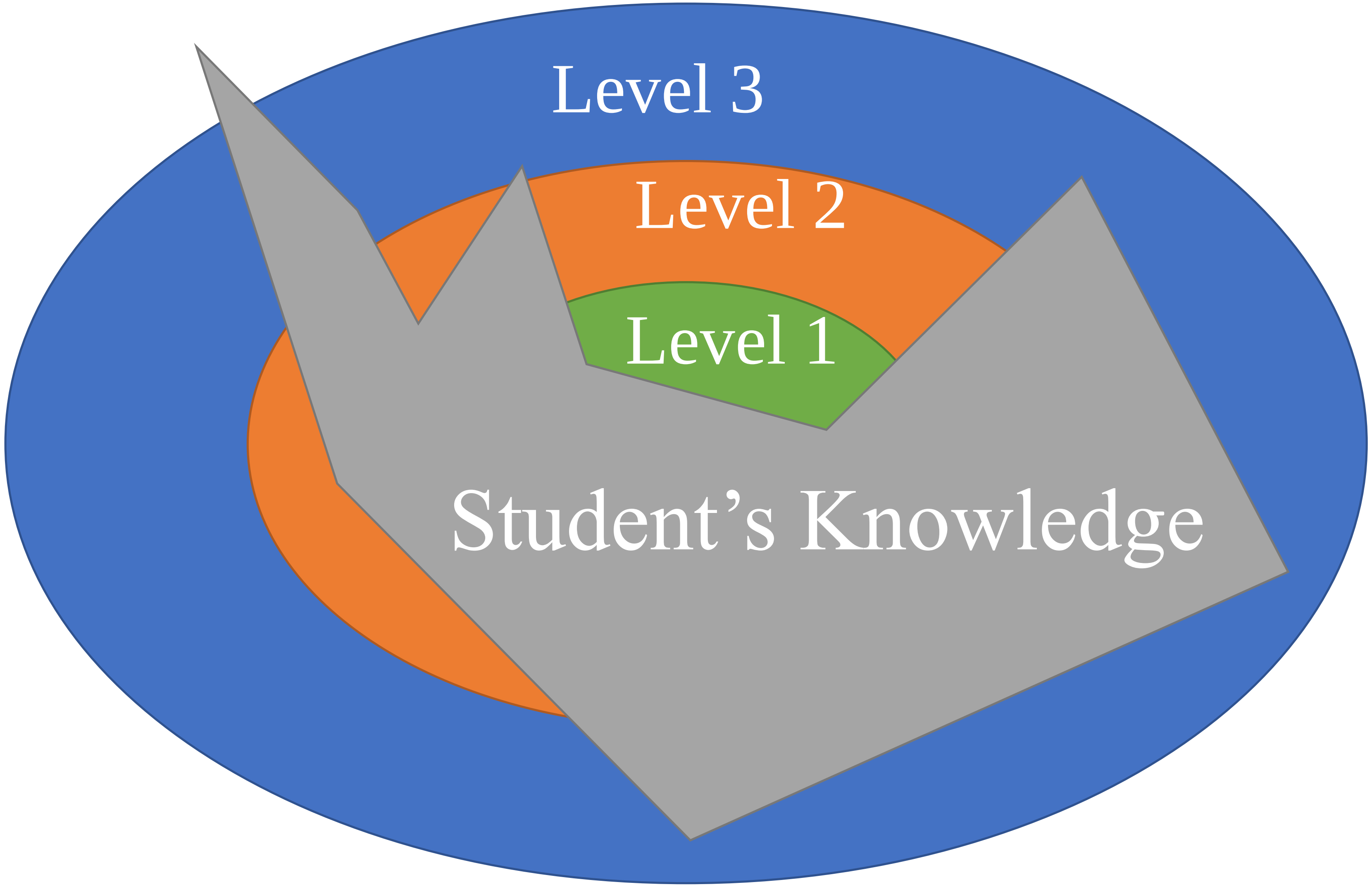
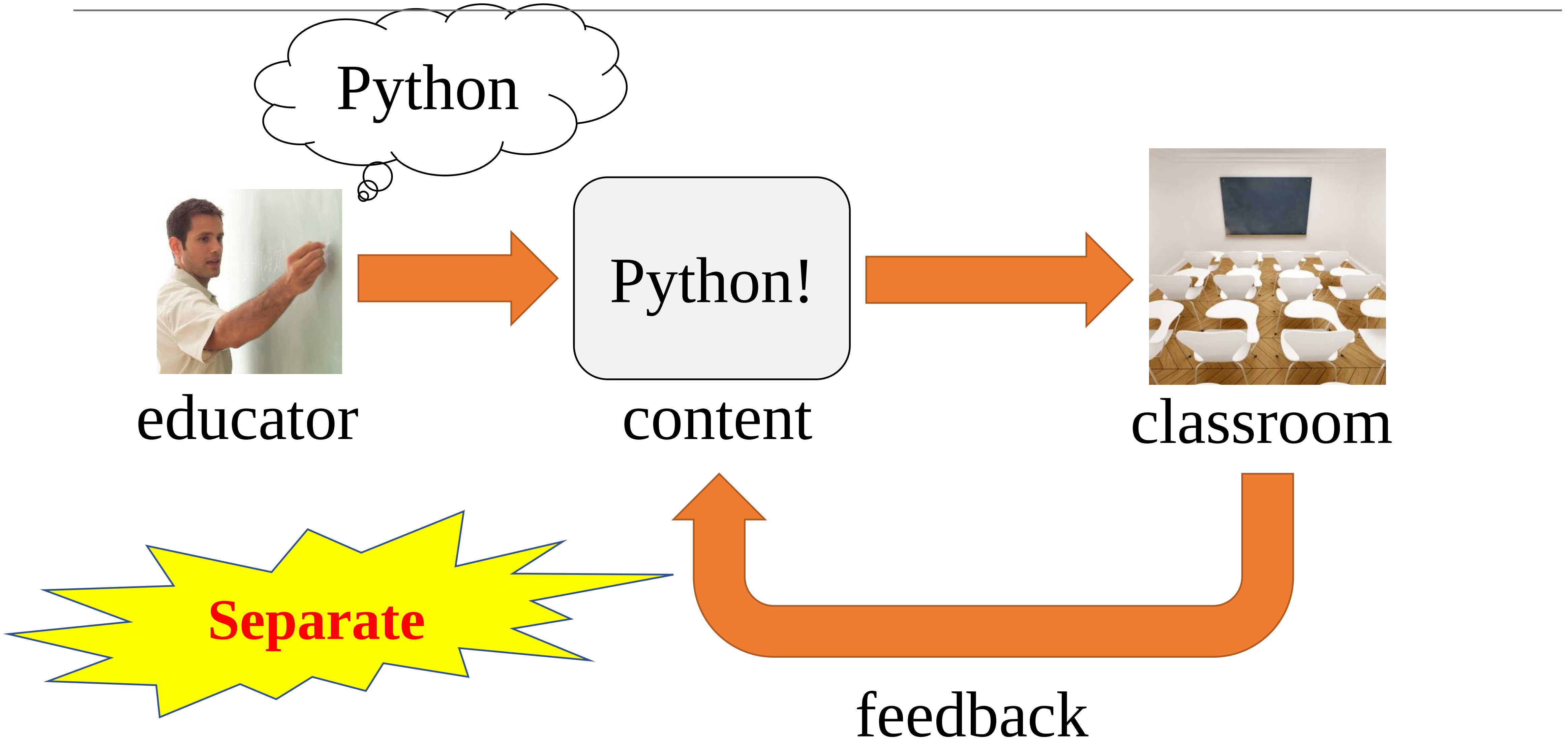
Cornell University

PEKING UNIVERSITY

Source: Center for Game Science

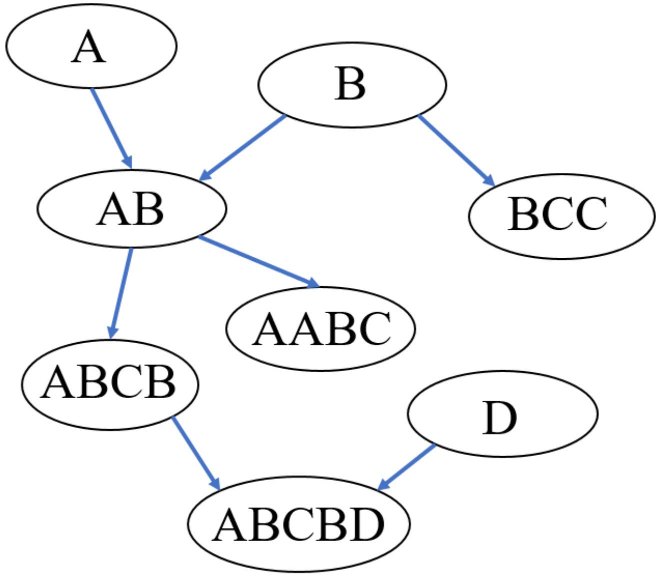

Level 3
Level 2
Level 1
Student's Knowledge

Current Education System

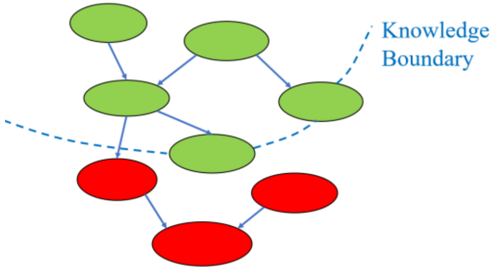


Our Unified Framework

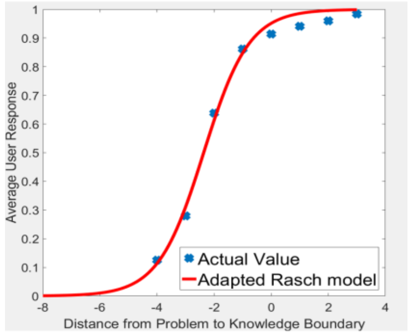
Framework



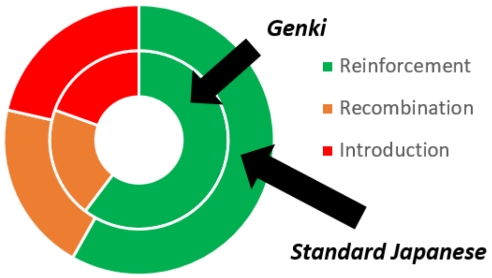
Knowledge Assessment



Performance Prediction



Learning Progression Analysis



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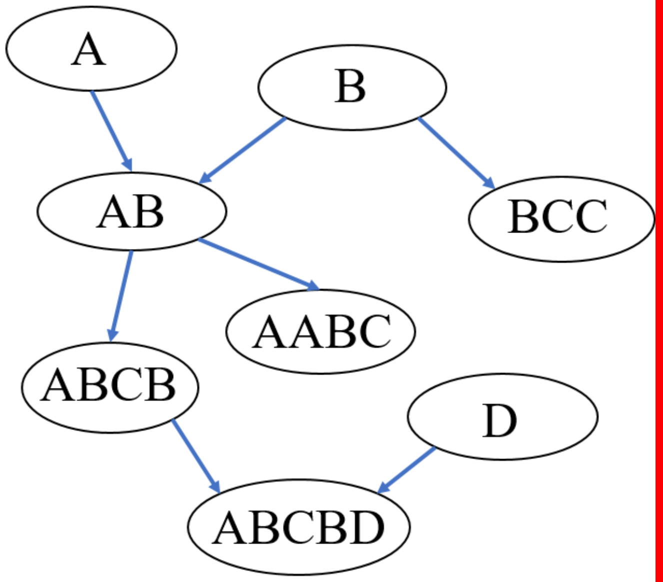

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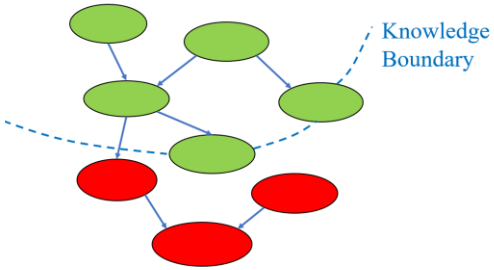

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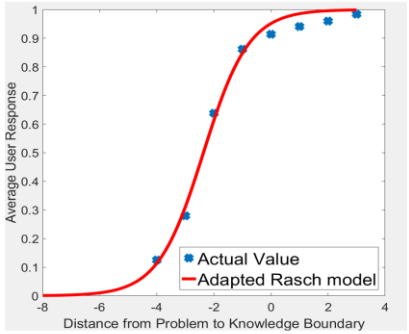

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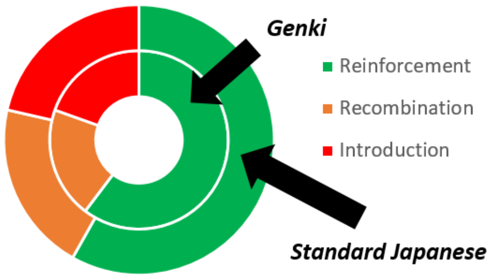


Knowledge Organization

Study the **relationship** between practice problems

&

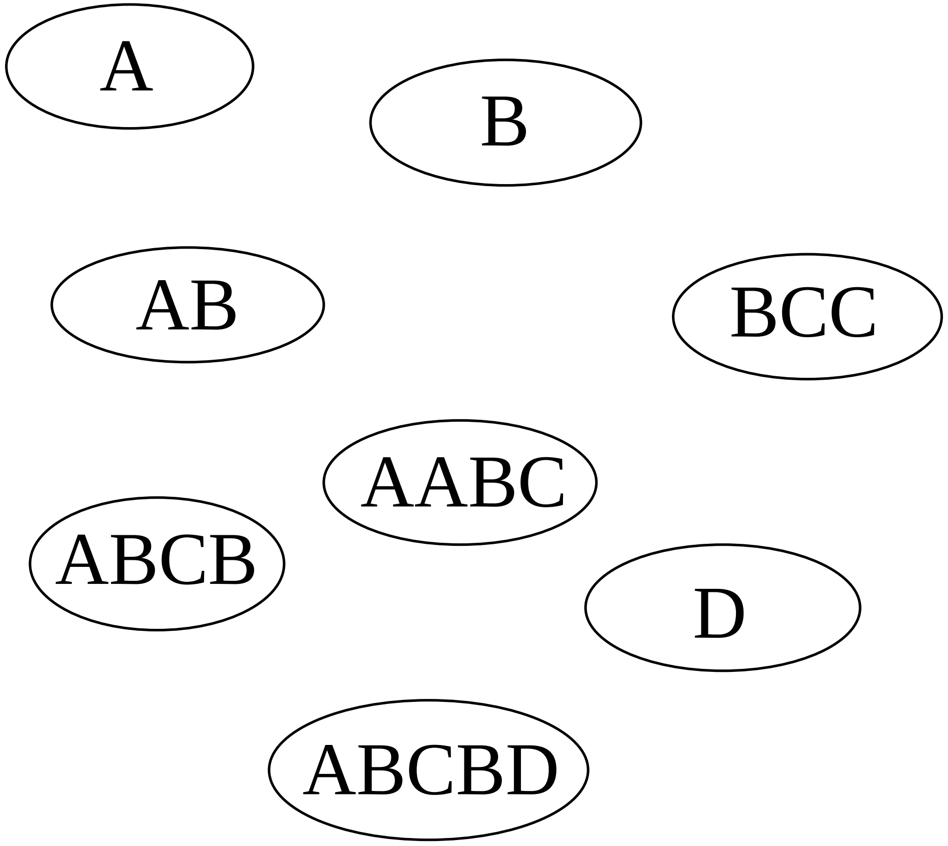
Build the **hierarchical structure**.

Partial Ordering on Practice Problems

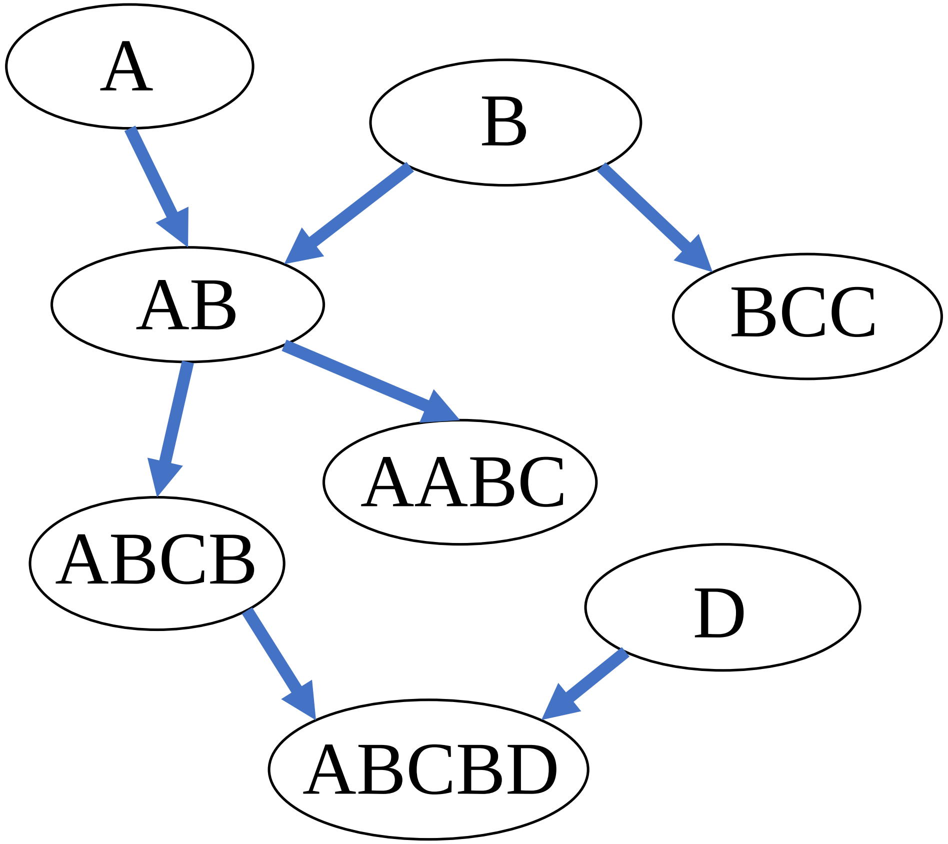
p_1 is at least as hard as p_2 if:

$$skills(p_1) \sqsupseteq skills(p_2)$$

Practice Problems



Partial Ordering Graph



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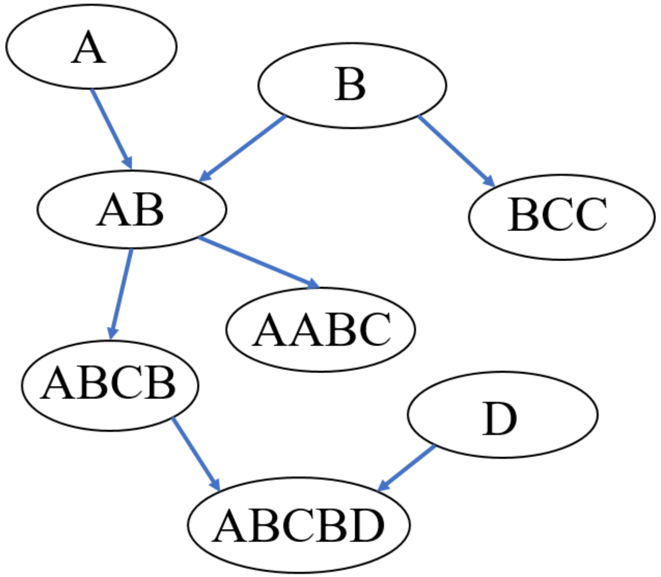

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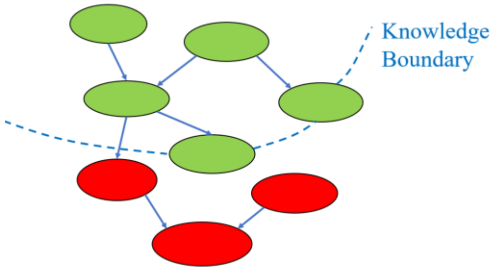

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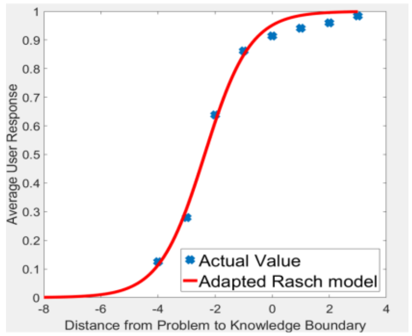

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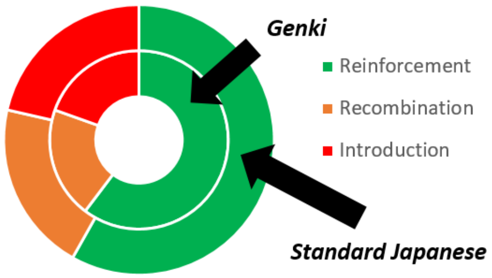
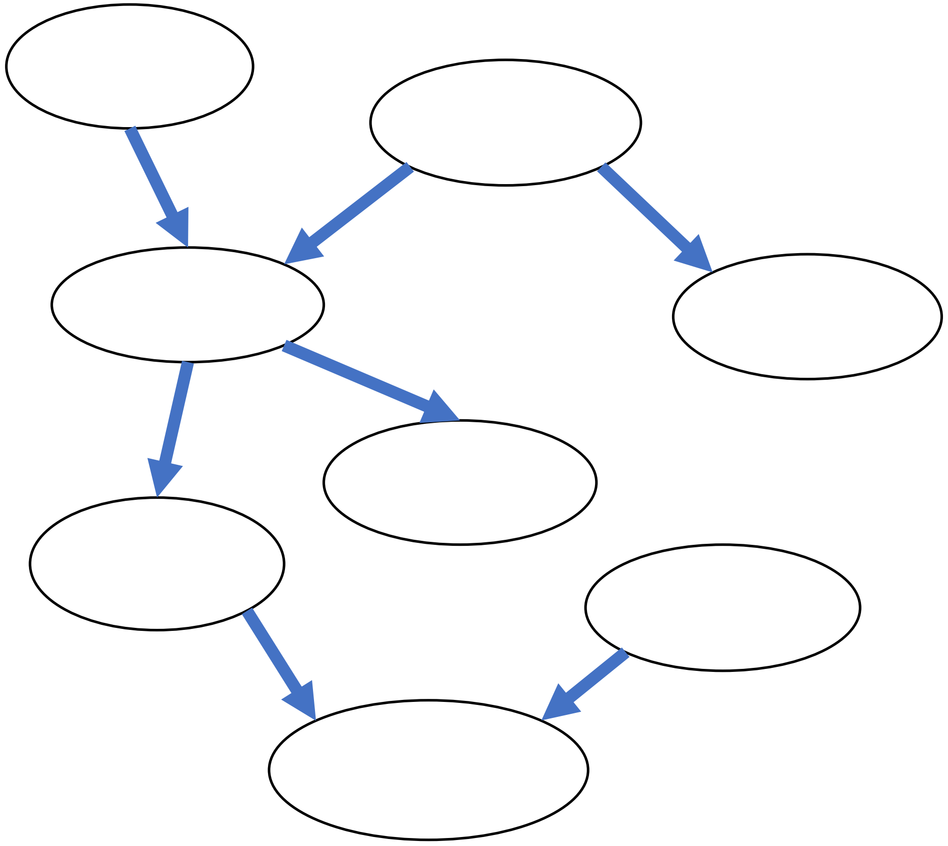


Property of Partial Ordering

If p_2 is at least as hard as p_1, then

- Students who understand p_2 will also understand p_1
- Students who don't understand p_1 will not understand p_2

Coloring Partial Ordering Graph



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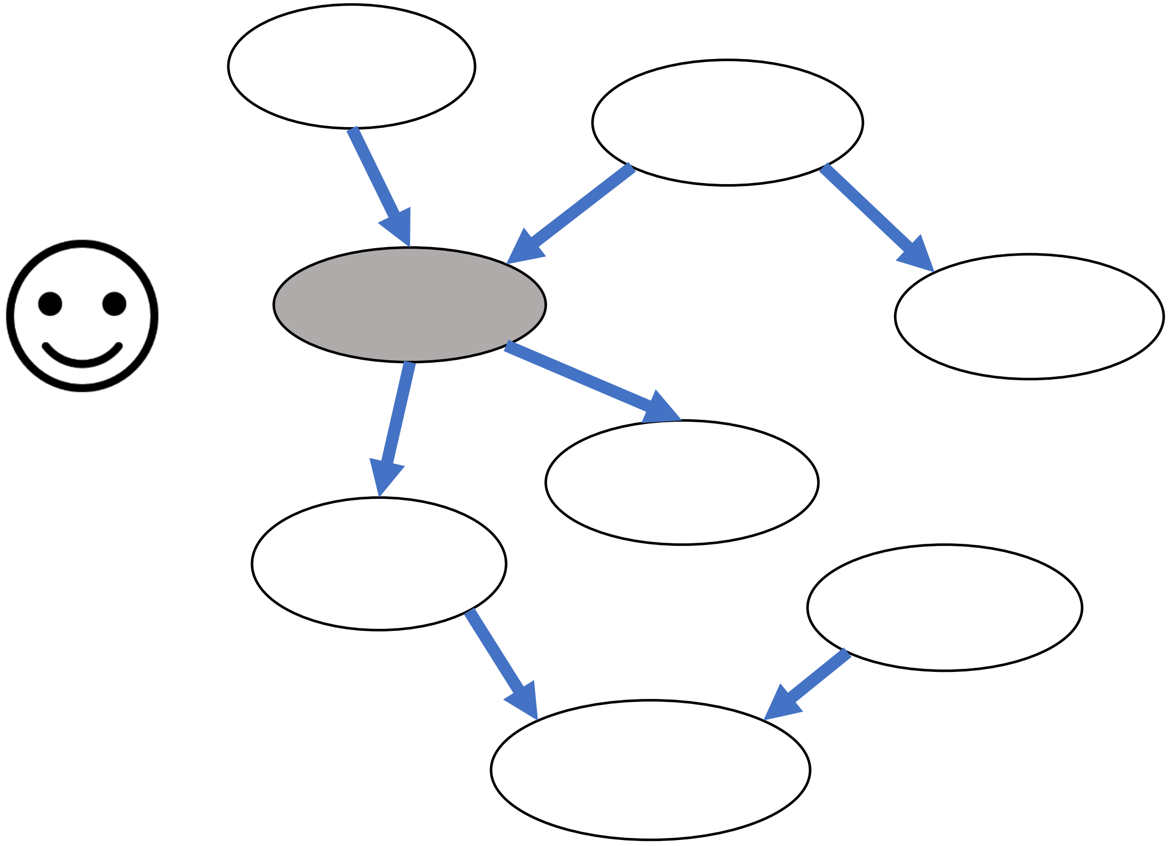

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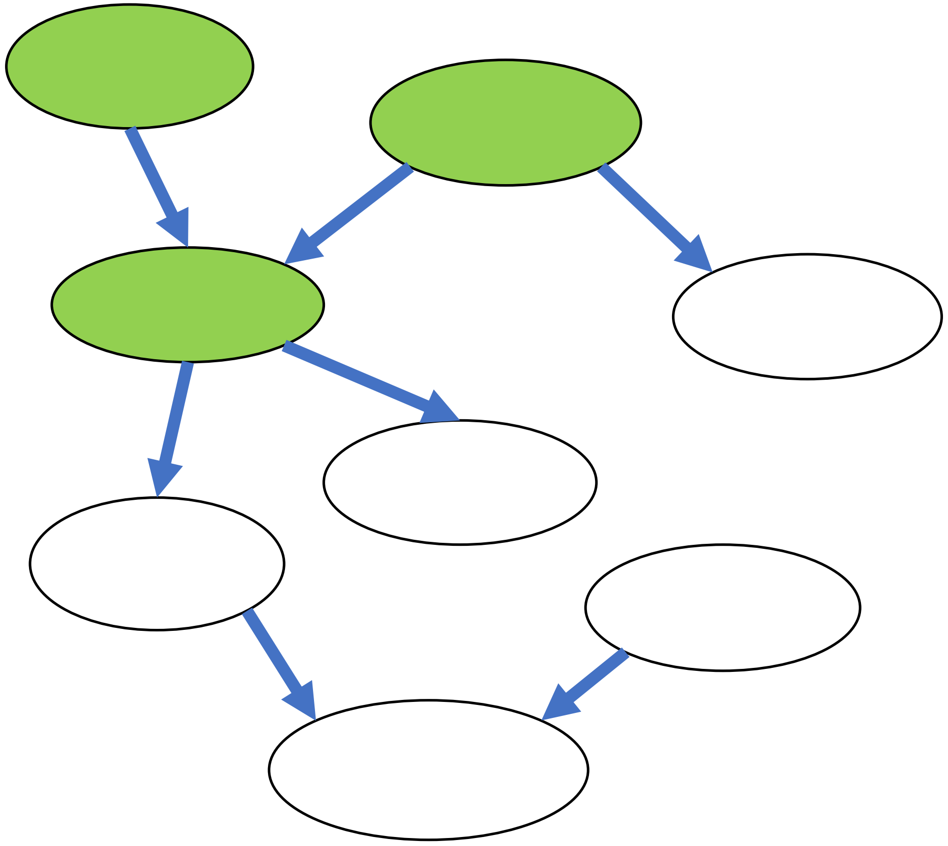

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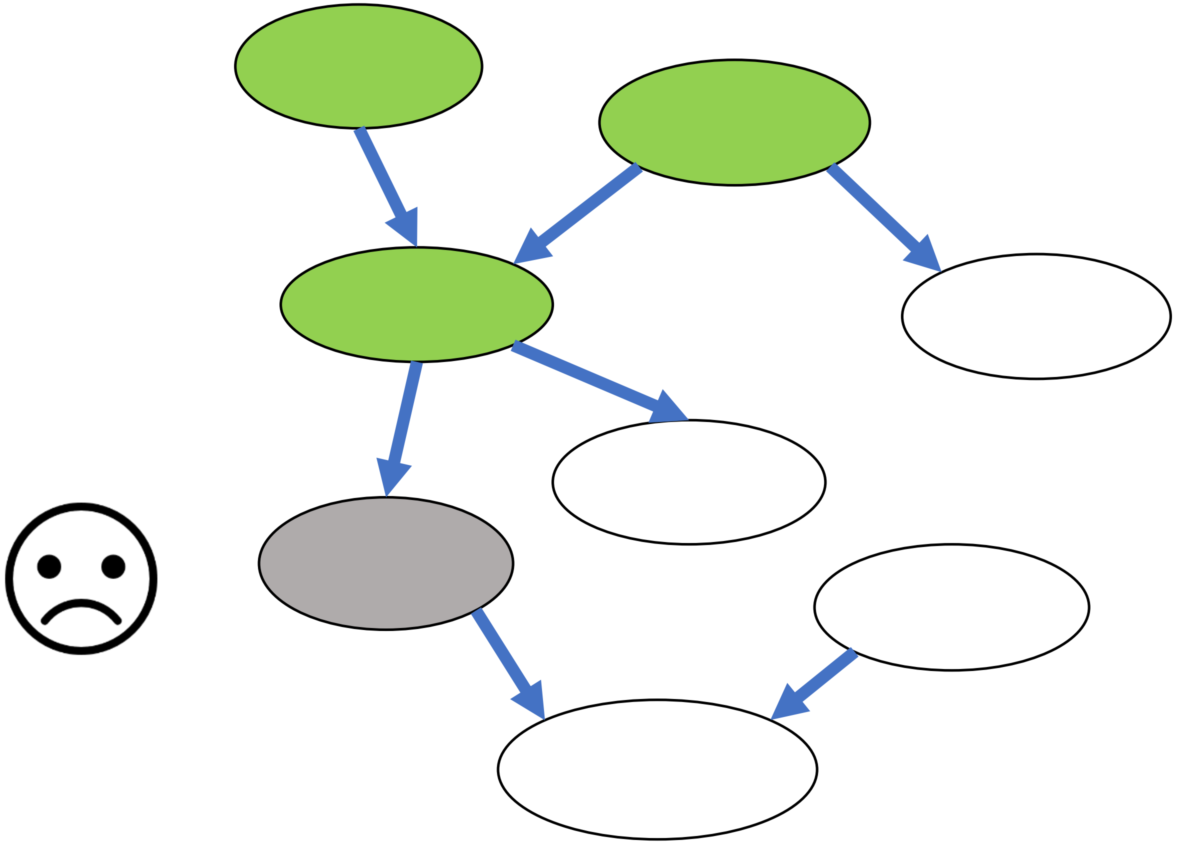

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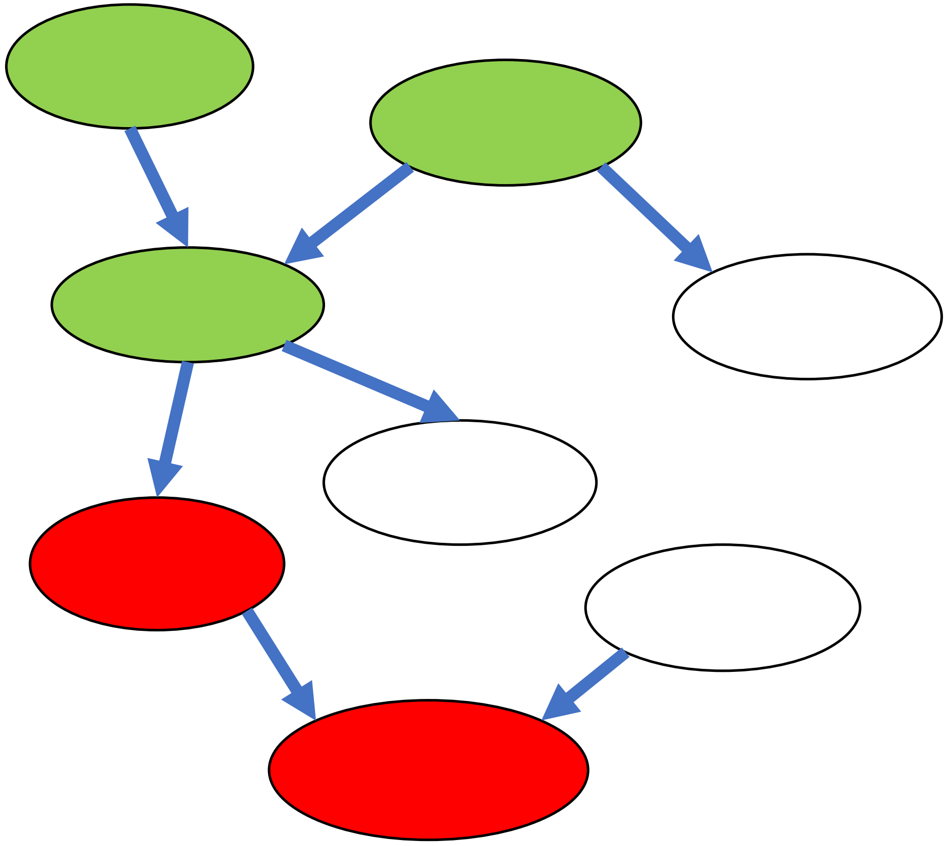

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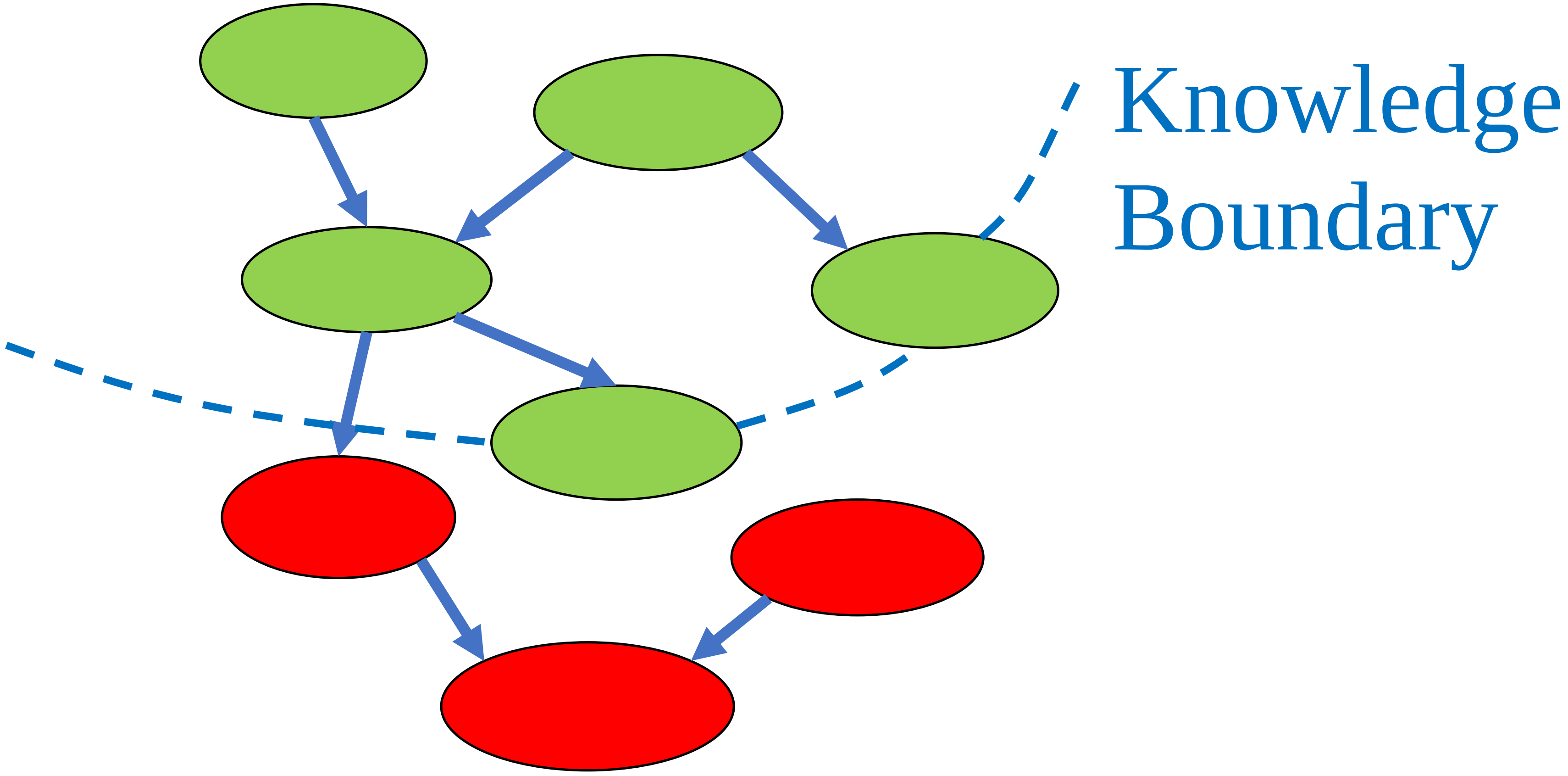


Knowledge Boundary

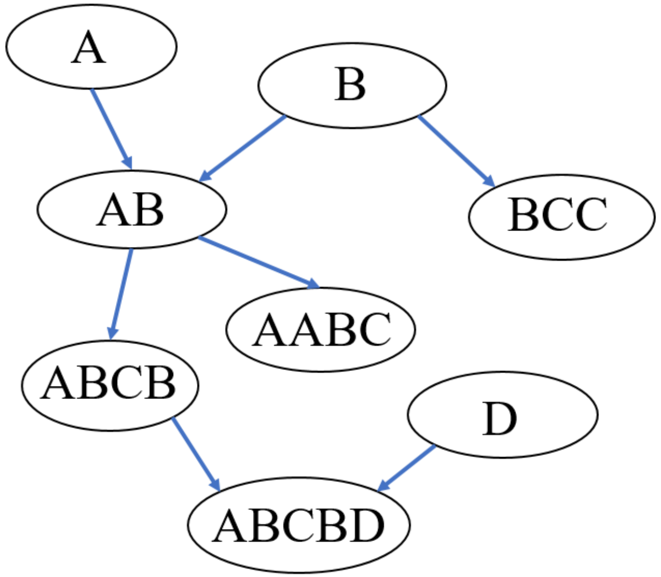
Knowledge Boundary (K.B.) :

the set of the hardest problems that a student can understand.

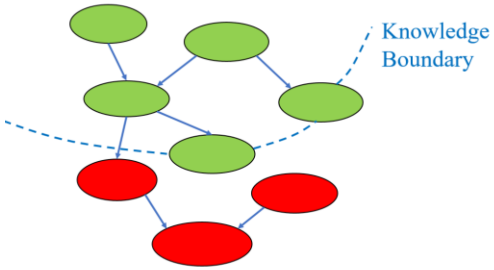
We use Knowledge Boundary to model a student's knowledge within the Partial Ordering Graph.

Our Unified Framework

Framework



Knowledge Assessment



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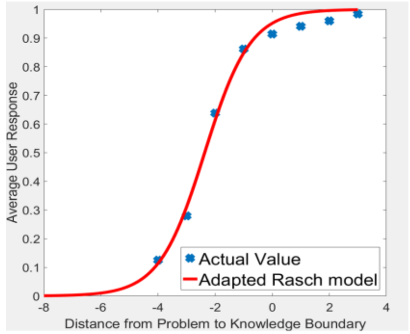
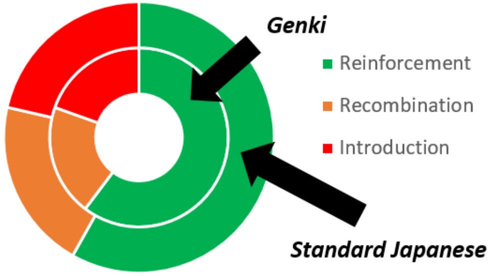


Learning Progression Analysis



Rasch Model

Student Performance P is a function of the difference between the student's ability θ and the problem's difficulty b.

$$P(\theta, b) = \frac{e^{\theta - b}}{1 + e^{\theta - b}}$$

	Student Ability θ	**Problem Difficulty b**
Rasch Model	Unidimensional Numeric Scores	
Our Model	Knowledge Boundary	Node in Partial Ordering Graph

Distance to Knowledge Boundary

In order to measure the **difference** between

student ability θ and problem difficulty b,

We calculate the **distance** between

Knowledge Boundary and the problem(node) in Partial Ordering Graph.

Experiments: A Japanese Assessment Tool

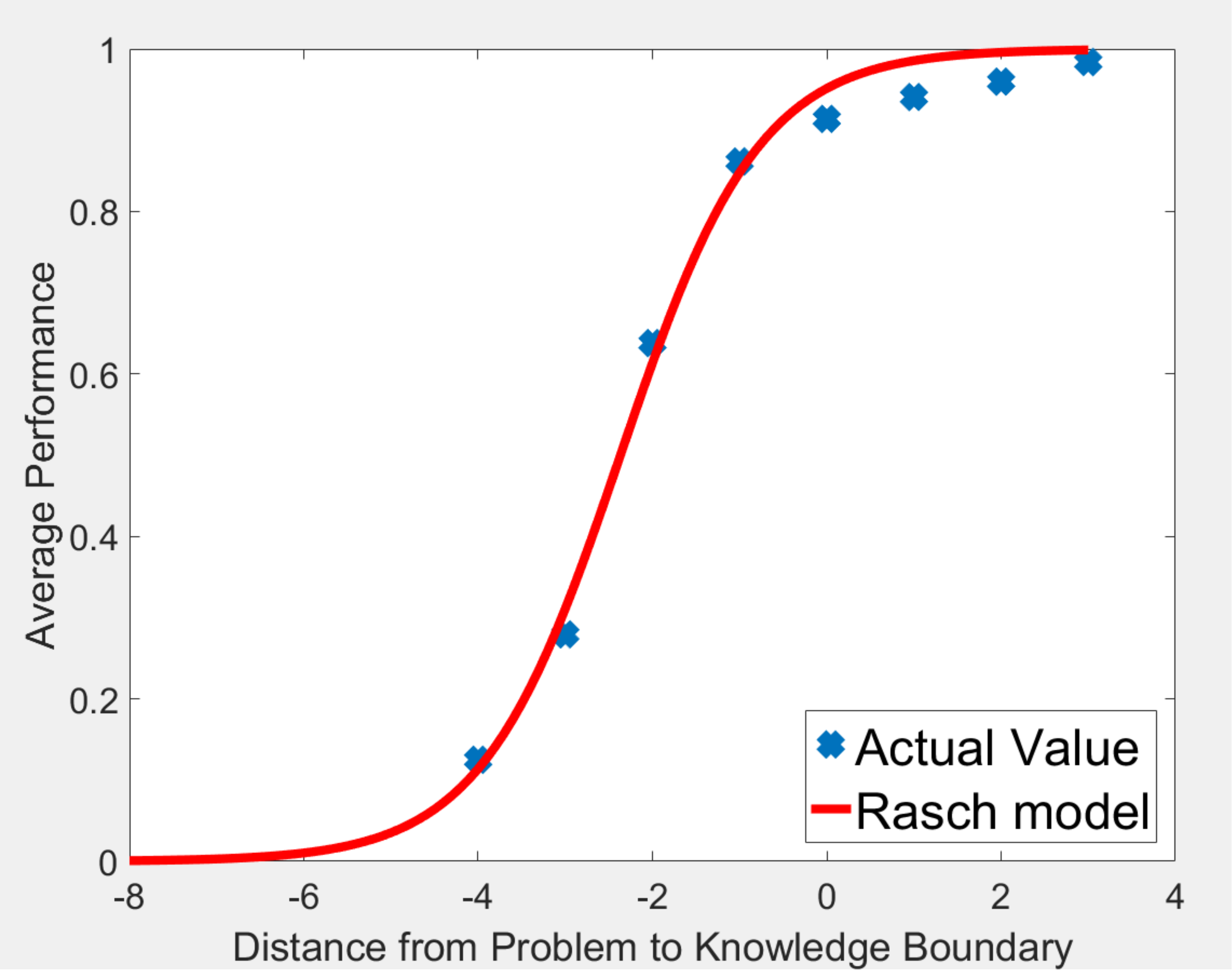
First 10 sentences:

- Students answered whether they can understand those sentences.
- The responses were used for assessing students’ knowledge.

Next 5-8 sentences:

- Students answered how well they understand those sentences.
- The responses were used as the test set for performance prediction

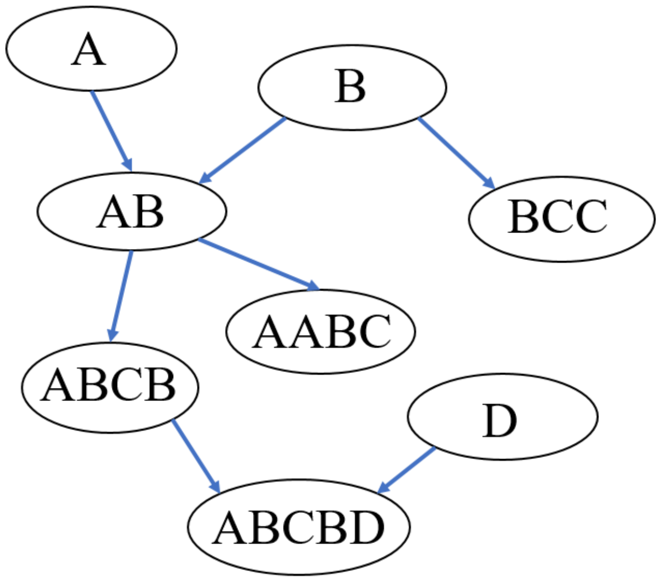
Results



1
0.8
0.6
0.4
0.2
0
Average Performance
-8
-6
-4
-2
0
2
4
Distance from Problem to Knowledge Boundary
Actual Value
Rasch model

Our Unified Framework

Framework



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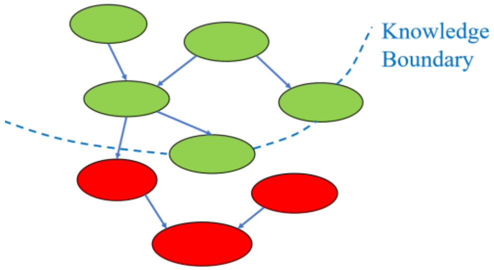

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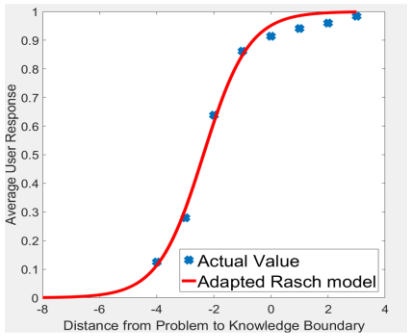
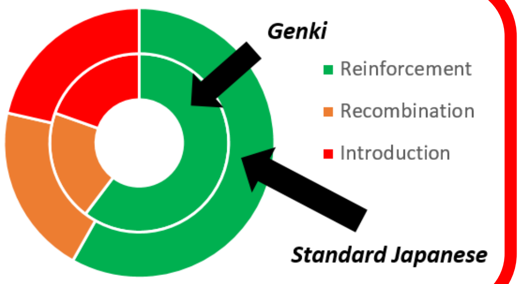
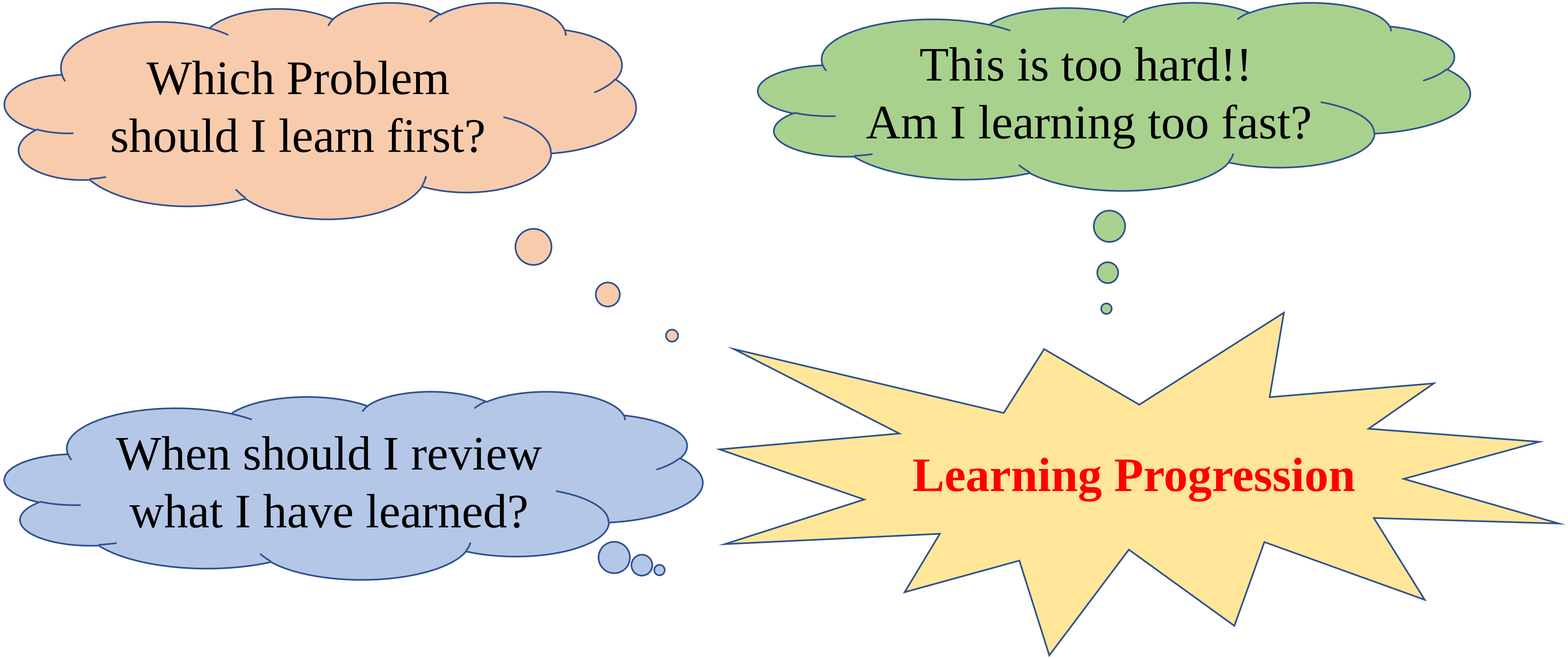


Learning Progression Analysis



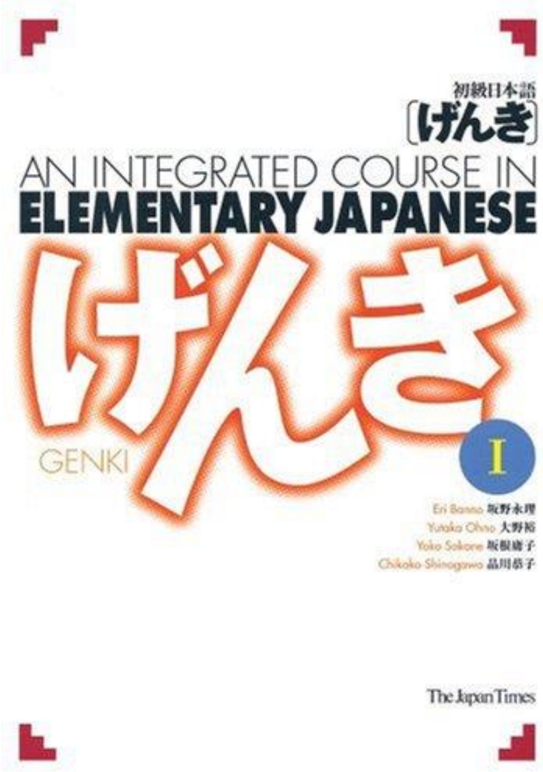
When I have a “Library” of practice problems



In order to automatically design learning progressions,

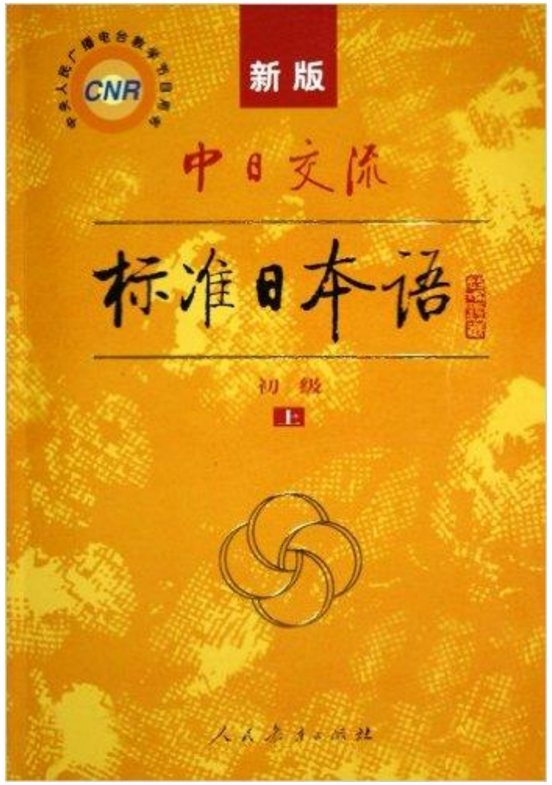
we need to study **expert-designed learning progressions**.

Progression Analysis on Textbooks



Genki

Standard Japanese



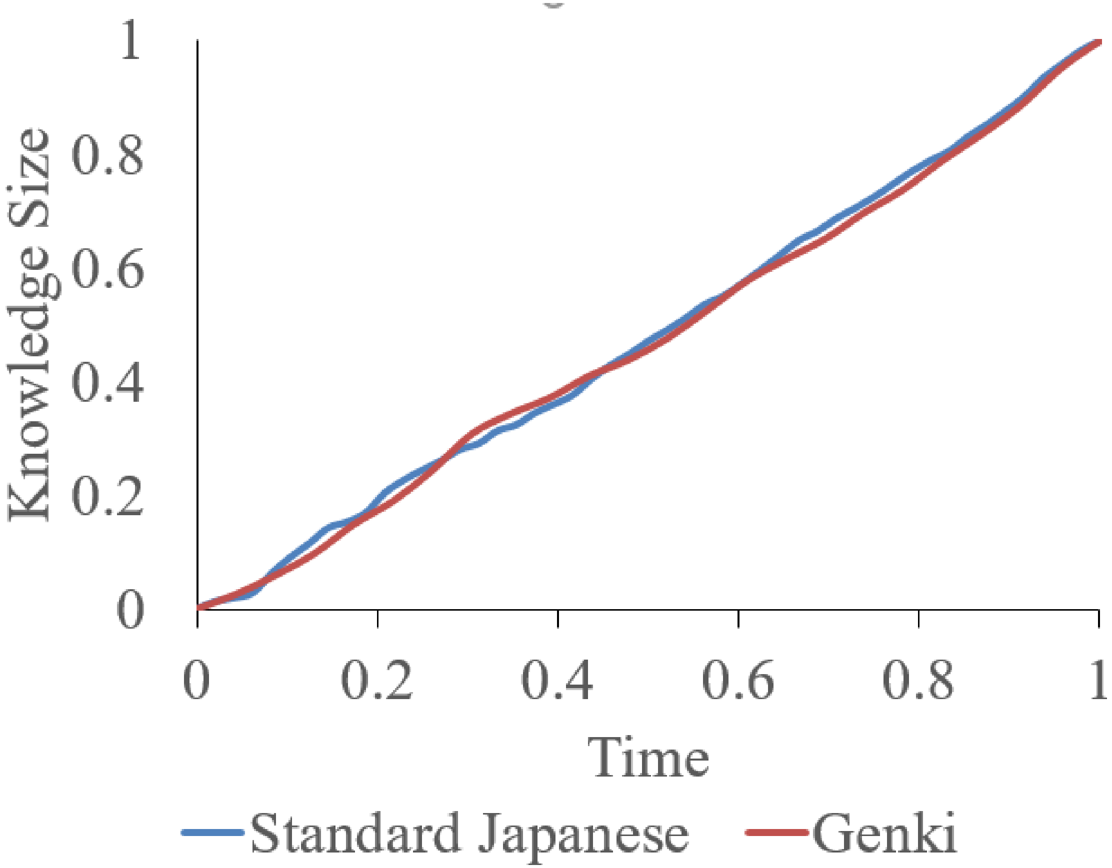
We are Looking for <u>General Principles</u> of designing good learning progressions.

Progression Metric: Learning Pace

A student's $Knowledge\ Size$ is number of problems p s.t. the student has learned p or some other problem that is harder than p.

$$Pace = \frac{\Delta Knowledge\ Size}{\Delta time}$$

Both textbook progressions are following a similar, steady pace.

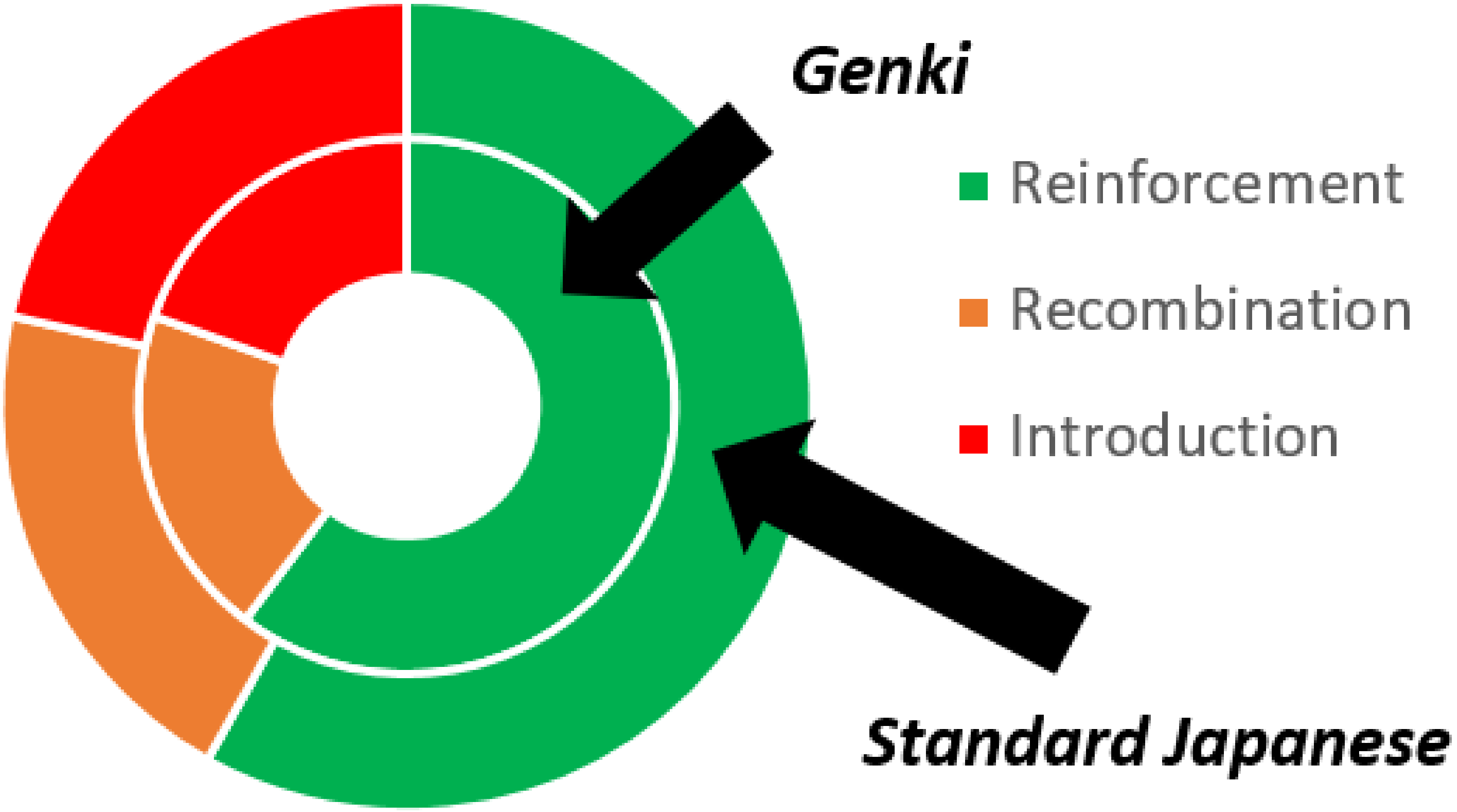


Progression Metric: Balance of Learning and Review

We classify problems in a learning progression into Introduction, Reinforcement and Recombination.

Problem	Knowledge	Classification
1	A	Introduction
2	B	Introduction
3	BC	Introduction
4	A	Reinforcement
5	C	Reinforcement
6	ABC	Recombination

Progression Metric: Balance of Learning and Review



Future work

- Apply to Different Educational Domains
  - Especially Computer-Assisted Language Learning (CALL)
- A Science of Progression Analysis
  - Pacing and Sequencing: Find the Best Principles.
- Automatic and Adaptive Tutoring System
  - Rapid Initial Assessment
  - Progression Tailoring

Summary

- Organizing Practice Problems into **Partial Ordering Graph**
  - A hierarchical structure of knowledge
- Knowledge Assessment within Partial Ordering Graph
  - **K**nowledge **B**oundary -- student modeling
  - Distance to **K.B.** -- performance prediction
- Analyzing Learning Progressions from Textbooks
  - Learning pace
  - Balance of Learning and Review