# DINA-FOHM Model on Rational Number Knowledge

By Senuvi Vidara and Jessica Gong

Mentor: Trung

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## Introduction

#### **Based on Research Paper**

The Researchers' Goal: Find whether two different feedback modes on a math test is effective in promoting learning AND develop models to diagnose individual learning tracks over time

OUR Goal: Validate and expand on their findings through 1) descriptive analysis and 2) fitting a new model, DINA-FOHM

Tang, F., & Zhan, P. (2021). Does Diagnostic Feedback Promote Learning? Evidence From a Longitudinal Cognitive Diagnostic Assessment. AERA Open, 7. <u>https://doi.org/10.1177/23328584211060804</u>

### Key Terms

Cognitive diagnostic assessment (CDA)  $\rightarrow$  latent attributes Rational number operations

Cognitive diagnostic feedback (CDF)  $\leftrightarrow$  knowledge of correct response (KCR)  $\leftrightarrow$  Diagnostic Group

Correct-incorrect response feedback (CIRF) ↔ knowledge of correct response plus additional information (KCRI) ↔ Traditional Group

No feedback  $\leftrightarrow$  Control Group

Diagnostic Feedback Report													
Student ID:													
Part I. Your Answers													
Multiple-Choice Items													
Item	1	2	3	4	5	6	7	8	9	10	11	12	
Answer Key	D	D	D	C	D	D	С	В	В	A	В	В	
Your Answer	D	D	D	В	С	B	С	Α	В	A	В	A	
Accuracy	V	V	V	×	×	×	$\checkmark$	×	×	V	V	×	
Calculation Items													
Item	13		14		1	15		16		17		18	
Correct Answer	21		-1		10	160		8/75		16		-13	
Your Answer	21		-1		160		16/75		9				
Accuracy	V		N			V	×		>	×		×	
Score: 9	Pa		(our )	fectors	Statu			dee Br	into				
H	Knowle	dge Poi	nt	lastery	Statu	Master	v or No	on-maste	erv	Pr	obabilit	v*	
A1: Rational Numbers						Yes				97%			
A2: Related Concepts of Rational Numbers						Yes				94%			
A3: Axis						No				11%			
A4: Addition and Subtraction of Rational Numbers						Yes				76%			
A5: Multiplication and Division of Rational Numbers						Yes				57%			
A6: Mixed Operation of Rational Numbers					No				33%				
Note, * means the of Attribute Master	legree o y Statu	of certain s: (A1,	nty of c A2, A	lassificat	ion.	b) = (11	0110)						







### 6 Latent Skills

**Knowledge Point** 

A1: Rational Numbers

A2: Related Concepts of Rational Numbers

A3: Axis

A4: Addition and Subtraction of Rational Numbers

A5: Multiplication and Division of Rational Numbers

A6: Mixed Operation of Rational Numbers

### Data Background

#### 276 grade 7 students

- Q matrix  $\rightarrow$  18x6
- ScoreA  $\rightarrow$  90x18x3  $\rightarrow$  Diagnosis Group
- Score  $B \rightarrow 92x18x3 \rightarrow$  Traditional Group
- ScoreC  $\rightarrow$  94x18x3  $\rightarrow$  Control Group

Diagnostic Feedback Report													
Student ID:													
Part I. Your Answers CIRF													
Multiple-Choice Items													
Item	1	2	3	4	5	6	7	8	9	10	11	12	
Answer Key	D	D	D	С	D	D	С	В	В	Α	В	В	
Your Answer	D	D	D	В	С	В	С	A	В	A	В	A	
Accuracy	V	$\checkmark$	$\checkmark$	×	×	×	V	×	×	V	$\checkmark$	×	
Calculation Items													
Item	1	3	14		15		16		17		18		
Correct Answer	21		-1		160		8/75		16		-13		
Your Answer	21		-1		160		16/75		9				
Accuracy	V		V		١	1	×		×		×		
Score: 9													
Part II. Your Mastery Status of Knowledge Points													
Knowledge Point						Mastery or Non-mastery				Probability*			
A1: Rational Numbers						Yes				97%			
A2: Related Concepts of Rational Numbers						Yes				94%			
A3: Axis						No				11%			
A4: Addition and Subtraction of Rational Numbers						Yes				76%			
A5: Multiplication and Division of Rational Numbers						Yes				57%			
A6: Mixed Operation of Rational Numbers					No 33%								
Note, * means the degree of certainty of classification. Attribute Mastery Status: (A1, A2, A3, A4, A5, A6) = (110110)													

## **Descriptive Analysis**



Within group trends over time

Between group trends

- t=1, similar bimodal distributions
- Diagnosis vs Control over time

## **DINA-FOHM Model**

# **Our Model**

### **DINA-FOHM**

Deterministic Inputs, Noisy "And" Gate First Order Hidden Markov

#### What is DINA Model?

- DINA (Deterministic Inputs, Noisy "And" gate) model is a Cognitive Diagnosis Model (CDM).
- It assesses whether individuals have mastered specific skills or attributes based on their responses to the test item.
- Core idea: Correct responses require mastery of all relevant skills for an item
- Used in educational assessments to pinpoint skill gaps and tailor learning strategies.

### Key Components of the DINA Model



Q-Matrix:

• Each row represent an item, and each column represent a skill.

Latent Attributes (Skills):

• Unobserved binary variables indicating whether an examinee has mastered a certain skill

Slip and Guess Parameters:

- Slip: The probability that an examinee who has not mastered all required skills answers an item incorrectly.
- Guess: The probability that an examinee who has not mastered all required skills answers an item correctly.

## **Findings and Results**

#### **Questions of Interest**

- Which question items are not good for measuring students' latent abilities?
- Whether certain skill combinations are systematically harder to master?
- What does the learning trajectory of each feedback group look like?

#### **Identifying Problematic Question Items**

#### Key Metrics:

- Slipping Probability (ss\_EAP): Indicates likelihood of answering incorrectly despite mastery.
- **Guessing Probability (gs\_EAP)**: Indicates likelihood of answering correctly without mastery.
- Ideal questions should have low ss\_EAP and gs\_EAP (< 0.25).

#### Findings:

- Look at >0.25 on graph
- Indicates poor alignment with latent abilities and reduced reliability
- No significant differences between groups



### **Posterior Item Skill Probabilities (PIS)**

#### At t = 0

64 possible latent skill combinations (ex. 101000)

No significant difference between 3 groups but...

#### Outliers in all 3 groups

skills <chr></chr>	avg_probability <dbl></dbl>
000001	0.09948990
000111	0.03098987
101111	0.11105756
110001	0.03152636
111101	0.03503472
111111	0.11824748



#### Learning Trajectory Across Feedback Groups



#### **Diagnosis Group:**

Latent Skill	Time Point 1	Time Point 2	Time Point 3
1	0.5738829	0.7832363	0.8978088
2	0.4451783	0.7675844	0.9027407
3	0.5405756	0.7521737	0.8765162
4	0.5902393	0.7792618	0.8871492
5	0.4954945	0.7218382	0.8558622
6	0.6757214	0.8398783	0.9249130

## Limitations

### **Limitations and Future Directions**

- No individual level view of skill mastery, just group level
- Possible practice effects from the parallel tests
- Small sample size (90 vs 92 vs 94 in the groups) for the 64 possible skill combinations

# References

Chen, Y., Culpepper, S. A., Wang, S., & Douglas, J. (2018). A Hidden Markov Model for LearningTrajectories in Cognitive Diagnosis With Application to Spatial Rotation Skills. Applied psychological measurement, 42(1), 5–23. <u>https://doi.org/10.1177/0146621617721250</u>

Tang, F., & Zhan, P. (2021). Does Diagnostic Feedback Promote Learning? Evidence From a Longitudinal Cognitive Diagnostic Assessment. AERA Open, 7. <u>https://doi.org/10.1177/23328584211060804</u>

## **Thank You!**