Detecting Learning Discontinuity for Out-of-tutor Events

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Agenda

- ❏ Introduction
- ❏ Data
- ❏ Methods
- ❏ Results
- ❏ Discussion
- ❏ Next Step

Introduction

- This project is tasked with developing a way to detect learning discontinuities within tutor log data to measure the effects of out-of-tutor events(Teacher interventions) in the Intelligent Tutoring System.
- Intervention: Teachers "monitors" the class and offer in-person help to students
- Research Questions:
  - Do these teacher interventions put students on a different learning trajectory, with respect to the specific skills?
  - How can we measure the effect of teacher interventions on learning?
- Purposes:
  - Improve Learning with tutor system
  - Improve scientific understanding of learning with ITS and teachers

Data - Transaction data

- 2 Datasets: Students transaction dataset & Student-Step dataset (Provided by Datashop)

- Transaction dataset: transaction time, **Student.Response.Subtype**, problem name, relevant KC, student actions, ...

- 104,550 observations. 195 Students (18 students never received tutor helps).

- **KC**: A Knowledge Component needed to solve related tasks. **7** KCs in our dataset. (Combine variable terms, Compute quotient for constant, etc)

...	Student.Response.Subtype	...	Problem.Name	Outcome	...	KC..Default.	...
...		...	x+3=5	CORRECT	...	Add/subtract_constant_from_both_sides	...
...	tutor-performed	...	x+7=7		...		...
...		...	x+7=7	CORRECT	...	Combine_constant_terms	...

Data - Student-Step Data

- Student-step dataset: **opportunity**, problem name, relevant KC, ….

- Used for the AFM model in the Datashop. Derived from Transaction dataset.

- **Opportunity**: An opportunity is the first chance on a step for a student to demonstrate whether he or she has learned the associated KC. Opportunity number increases by one each time the student encounters a step with the listed knowledge component.

- **Incorrect attempt**: once a student makes a mistake or asks for a hint in one attempt, we would call it an incorrect attempt.

…	Problem.Name	First.Attempt	…	KC..Default.	Opportunity..Default.	…
…	x+3=5	CORRECT	…	Add/subtract_constant_from_both_sides	4	…
…	x+7=7	CORRECT	…			…
…	x+7=7	CORRECT	…	Combine_constant_terms	5	…

Data - Preprocessing

Assumption: Followed by the teachers' intervention, students received the same or similar problem with KC associated what they have worked on with the teachers

Checking previous transaction

...	Student.Response.Subtype	...	Problem.Name	Outcome	...	KC..Default.	...
...	tutor-performed	...	x+7=7		...		...
...		...	x+7=7	CORRECT	...	Combine_constant_terms	...

Finding matching record

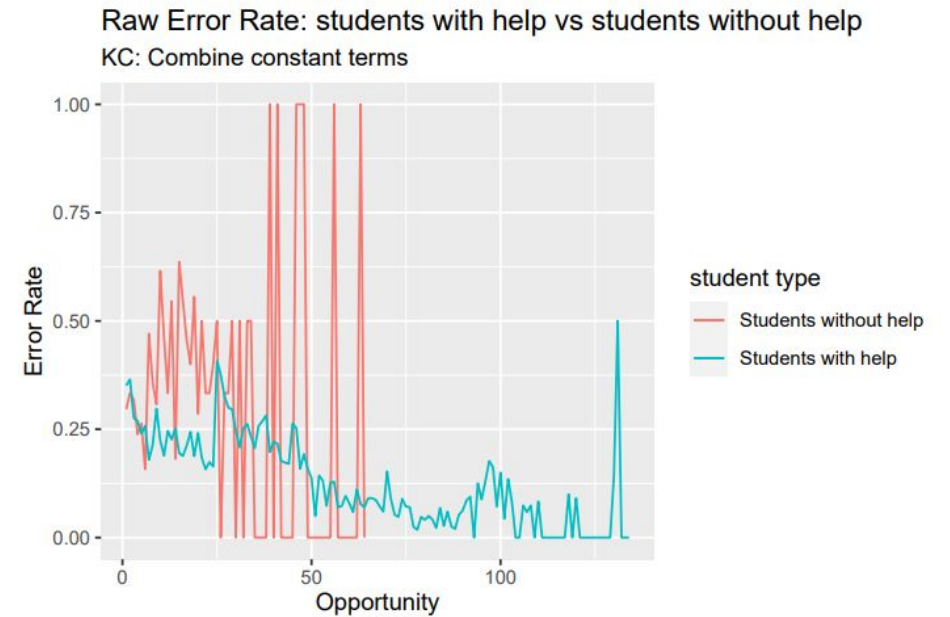| ...	Problem.Name	First.Attempt	...	KC..Default.	Opportunity..Default.	...	Teacher
...	x+7=7	CORRECT	...			...	0
...	x+7=7	CORRECT	...	Combine_constant_terms	5	...	1

Return 1

Data - Raw Error Rate for Two KC's

No obvious difference between students with help (97 students) and students without the help (84 students) For KC Divide both sides by the variable coefficient

Raw Error Rate: students with help vs students without help
KC: Divide both sides by the variable coefficient

* **Error rate**: the proportion of incorrect attempts among total attempts

Students without the help (27 students) have higher error rate than students with the help (168 students) at the beginning for KC Combine constant terms

Raw Error Rate: students with help vs students without help
KC: Combine constant terms

Methods - Part I

Log likelihood that student gets step correct

Students initial proficiency

Ease of the KC

How much student learned on prior opportunities for this KC

AFM:

$$ln\frac{p_{ij}}{1-p_{ij}} = \theta_i + \Sigma_k\beta_k Q_{kj} + \Sigma_k Q_{kj}(\gamma_k N_{ik})$$

Q_{kj} : (0 or 1) whether KC k is needed for step j

New AFM model for each KC(adding intervention "Pre/Post" to the model):

Log likelihood that student gets step correct in KC k

Students initial proficiency in KC

How much student learned on prior opportunities for this KC

$$ln\frac{p_{ik}}{1-p_{ik}} = \theta_{ik} + \gamma_k N_{ik} + \phi_k N_{ik}I_{ik} + \alpha_k I_{ik}$$

I_{ik} : teacher indicator, (0 or 1) whether the step is before or after first teacher intervention

i: the student
k: the knowledge component
j: the step

γ_k : gain for each opportunity to practice KC k

ϕ_k : adjusted the learning rate based on the intervention "Pre/Post"

α_k : adjusted the intercept based on the intervention "Pre/Post"

8

Methods - Part I

Our Assumption

- One intervention only influences problem-relevant KC(s)
- For each KC, we fit:

$$ln\frac{p_{ik}}{1-p_{ik}} = \theta_{ik} + \gamma_k N_{ik} + \phi_k N_{ik} I_{ik} + \alpha_k I_{ik}$$
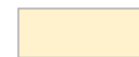
N: Opportunity
I: Pre(0)-Post(1) tutor indicator

Separation Method

Student 1	1	2	3	4	5
Student 2	1	2	3	4	5
Student 3	1	2	3	4	5

Pre
Post

Results - Part I

New AFM model
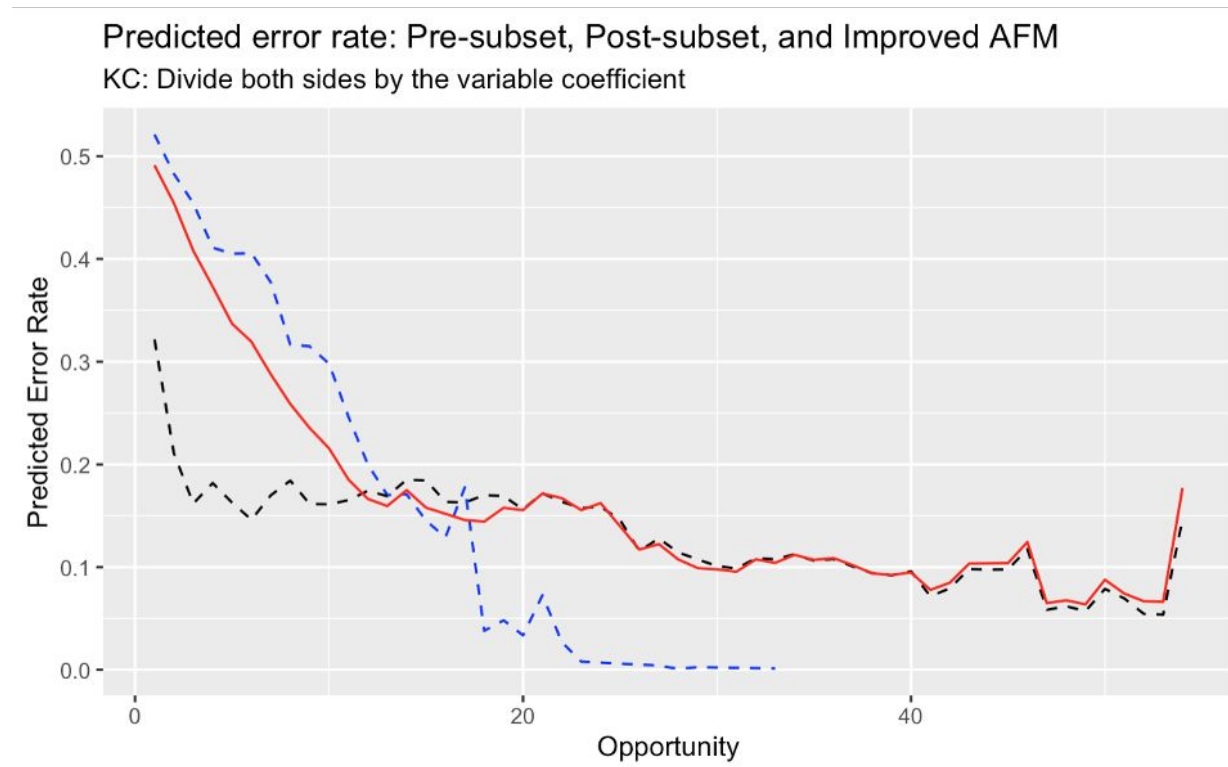
Predicted error rate: Pre-subset, Post-subset, and Improved AFM
KC: Divide both sides by the variable coefficient

- Three curves
  - Blue: AFM model for pre-teacher subset
  - Black: AFM model for post-teacher subset
  - Red: New AFM model
- New AFM model: "combining two curves"
- 97 students (1954 observations) took questions related to this KC
- 496 observations in Pre-subset, 1458 observations in Post-subset
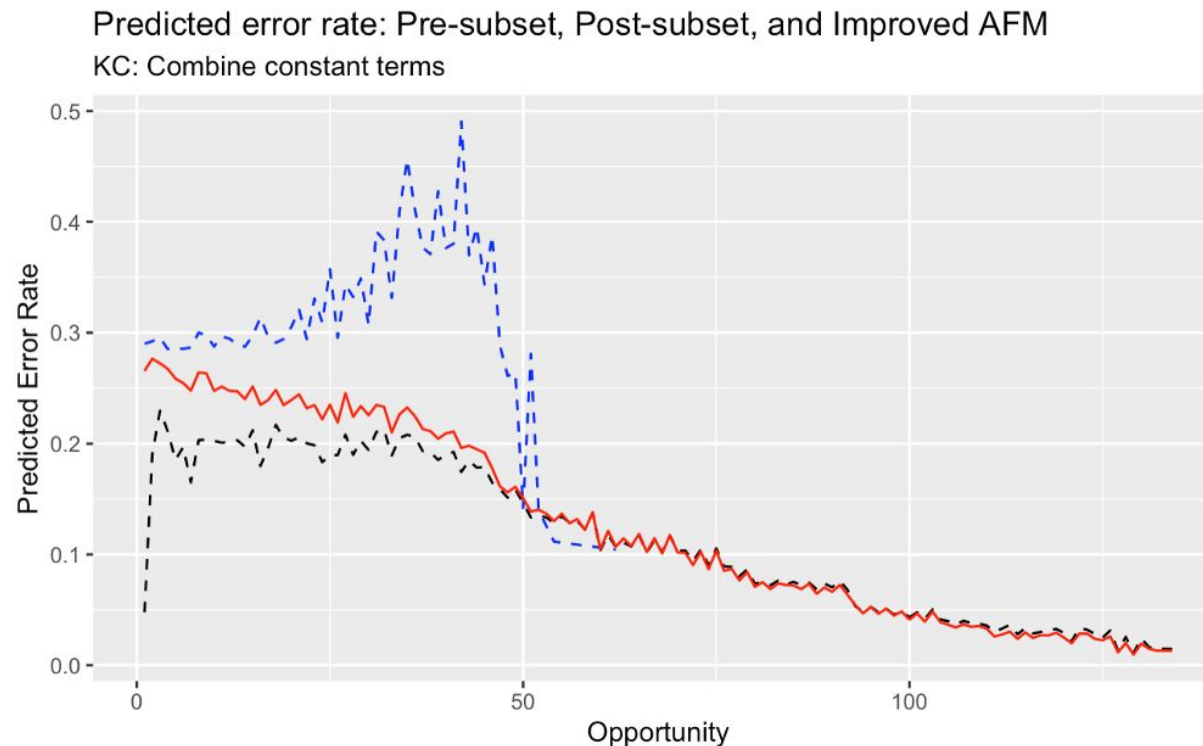- Observe a negative coefficient of the interaction term

Results - Part I

Model coefficients - Divide both sides by variable coefficient

Variable	Coefficient	P-value
Intercept	0.16770	0.581
Teacher-indicator	2.19549	2.93e-12 (***)
Opportunity	0.19765	2.38e-11 (***)
Teacher-indicator * Opportunity	-0.18750	7.09e-10 (***)

- **Positive effects of the indicator variable and opportunity**
- **Observe a negative coefficient of the interaction term**
- **Negative effect of the interaction between indicator variable and opportunity**

Results - Part I

New AFM model

Predicted error rate: Pre-subset, Post-subset, and Improved AFM
KC: Combine constant terms

- Three curves
  - Blue: AFM model for pre-teacher subset
  - Black: AFM model for post-teacher subset
  - Red: New AFM model
- Improved AFM: "combining two curves"
- 167 students (1954 observations) took questions related to this KC
- 1822 observations in Pre-subset, 6463 observations in Post-subset
- Observe a negative coefficient of the interaction term

Results - Part I

Model coefficients - Combine constant terms

Variable	Estimated	P-value
Intercept	1.412823	0.581
Teacher-indicator	0.207024	0.1117
Opportunity	0.010867	0.0632
Teacher-indicator* Opportunity	-0.003915	0.5139

- Positive effects of the indicator variable and opportunity
- Observe a negative coefficient of the interaction term
- Negative effect of the interaction between indicator variable and opportunity

Current Findings

- Positive coefficient for teachers' intervention suggests that teachers' intervention improved students' performances

- Positive coefficient for opportunity suggests students' natural improvement

- Negative coefficients for the interaction term of teacher intervention and opportunity

- Eventually, all students switched from Pre-subset to Post-subset. For example, few students are left in the Pre-subset after Opportunity 20 in KC: Divide both sides by variable coefficient.

- Students who received teachers intervention at different time might exhibit different learning rate from each other.
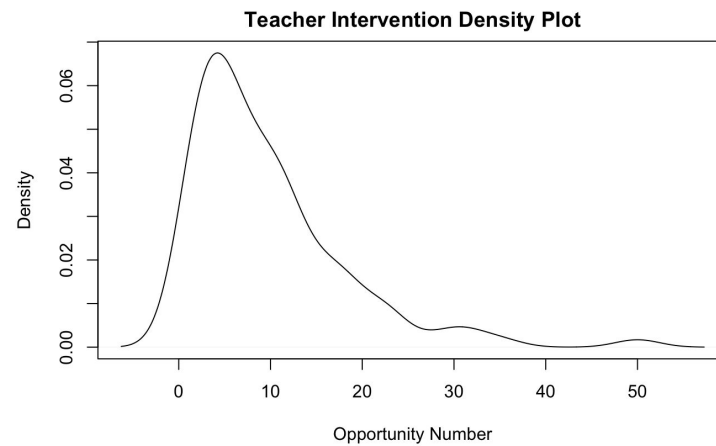
Methods - Part II

Goal

- Check whether students who received teacher interventions at different times exhibit different learning rates

Steps

- For each KC, split the students into three groups:
  - Early Group: The first one-third of students who received teacher intervention
  - Late Group: The last one-third of students who received teacher intervention
  - Normal Group: The remaining students (approximately one-third of the total number of students)
- Compare the raw error rate of these three groups
- Compare the predicted error rate using Group AFM model
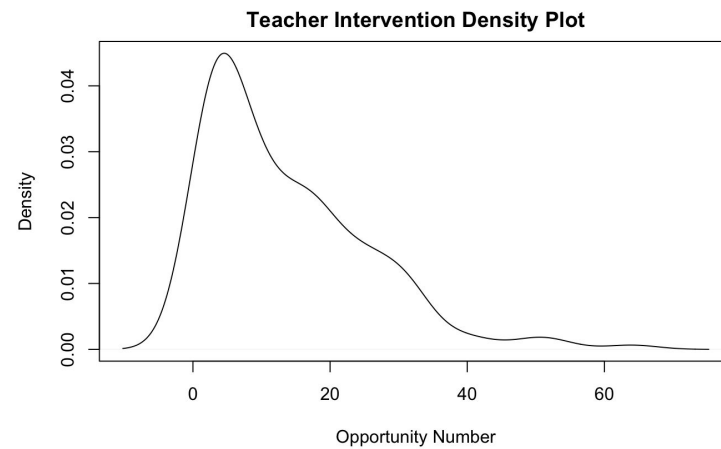
Methods - Part II

Teacher Intervention Distribution - KC: Divide both sides by the variable coefficient

Teacher Intervention Density Plot

Teacher Intervention	Number of student
Opportunity 1 ~ 4	31
Opportunity 5 ~ 11	37
Opportunity > 11	29

Methods - Part II

Teacher Intervention Distribution - KC: Combine constant terms

Teacher Intervention Density Plot

Teacher Intervention	Number of student
Opportunity 1 ~ 5	55
Opportunity 6 ~ 17	59
Opportunity > 17	53

Methods - Part II

New AFM model for each KC:

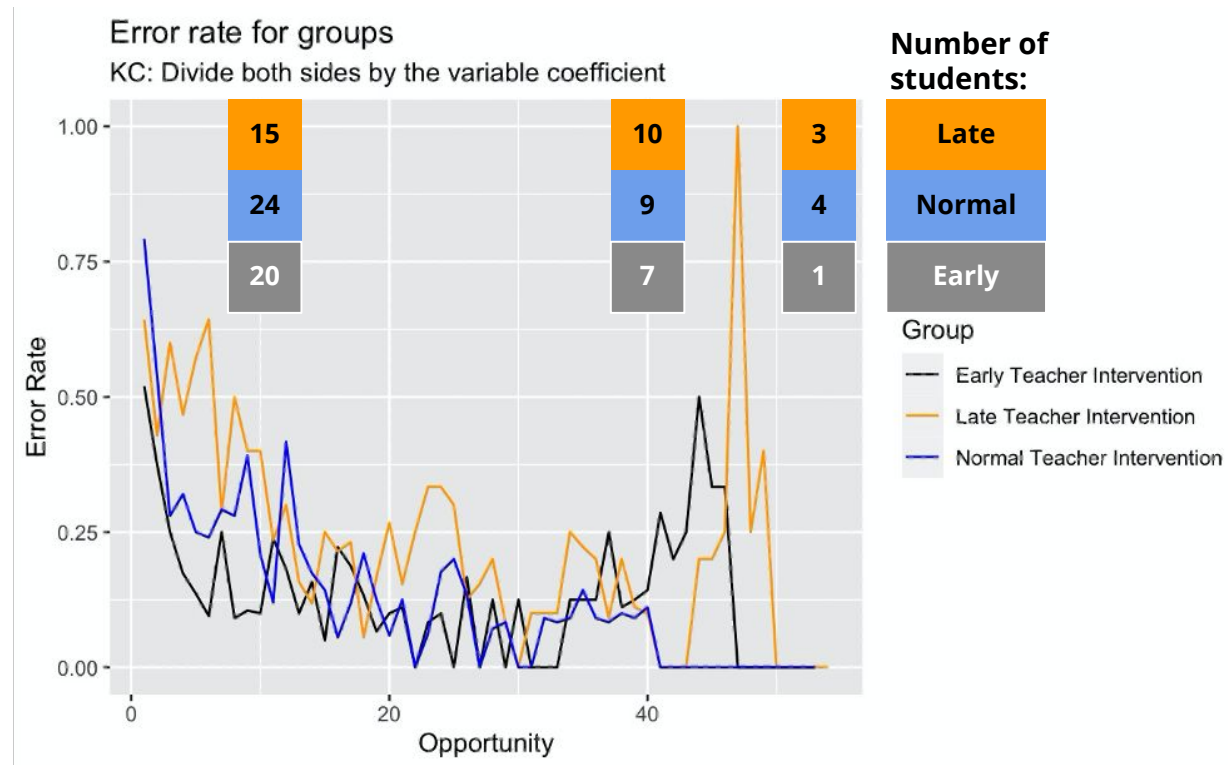$$ln\frac{p_{ik}}{1 - p_{ik}} = \theta_{ik} + \gamma_k N_{ik} + \phi_k N_{ik} I_{ik} + \alpha_k I_{ik}$$

I_{ik} : teacher indicator, (0 or 1) whether the step is before or after first teacher intervention

Group AFM model (adding group "Early/Normal/Late Teacher Intervention" to the AFM model):

$$ln\frac{p_{ik}}{1 - p_{ik}} = \theta_{ik} + \gamma_k N_{ik} + \psi_{km} N_{ik} G_{ik} + \lambda_{km} G_{ik}$$

G_{ik} : group indicator ("Early", "Normal" or "Late")

Results - Part II

Error rate for groups
KC: Divide both sides by the variable coefficient

Number of students:

15	10	3	Late
24	9	4	Normal
20	7	1	Early

Group
- Early Teacher Intervention
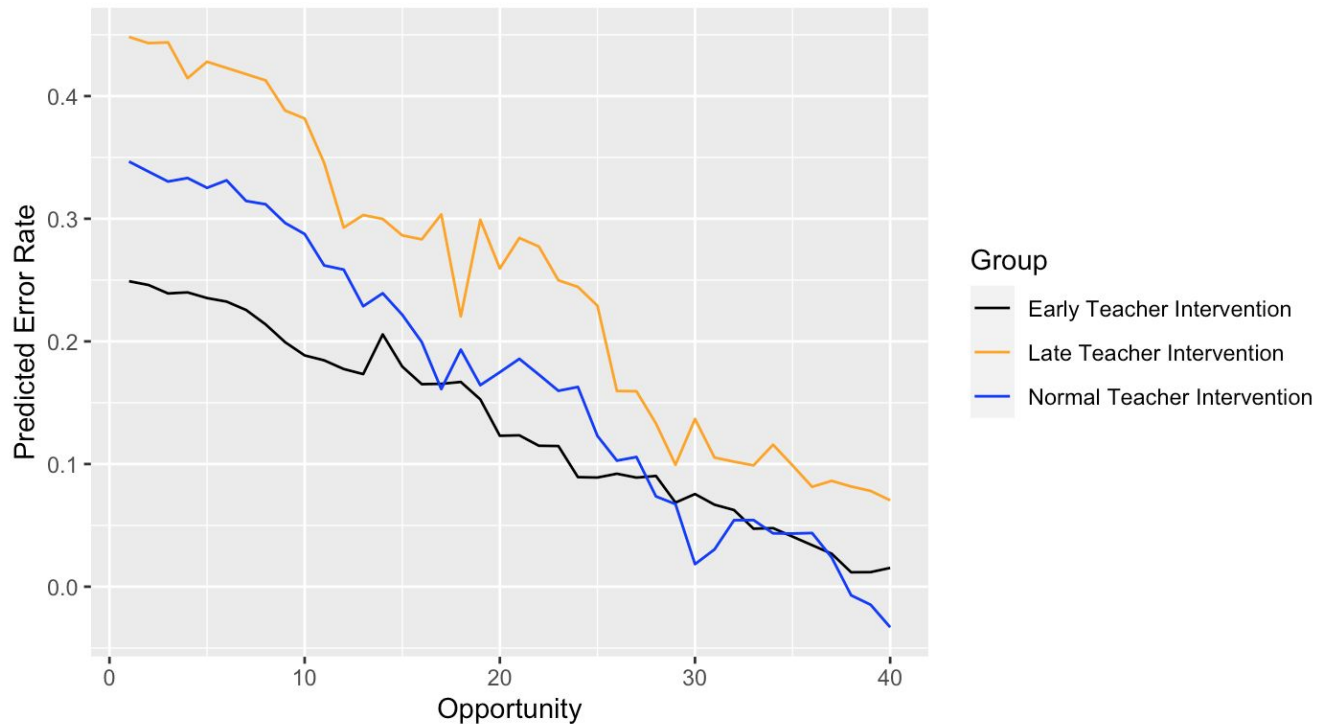- Late Teacher Intervention
- Normal Teacher Intervention

- Raw error rate
- Three curves
  - Black: error rate for students who received teachers' help in an early stage (opportunity<=4)
  - Blue: error rate for students who received teachers' help in a normal stage (4<opportunity<=11)
  - Orange: error rate for students who received teachers' help in a late stage (opportunity>11)
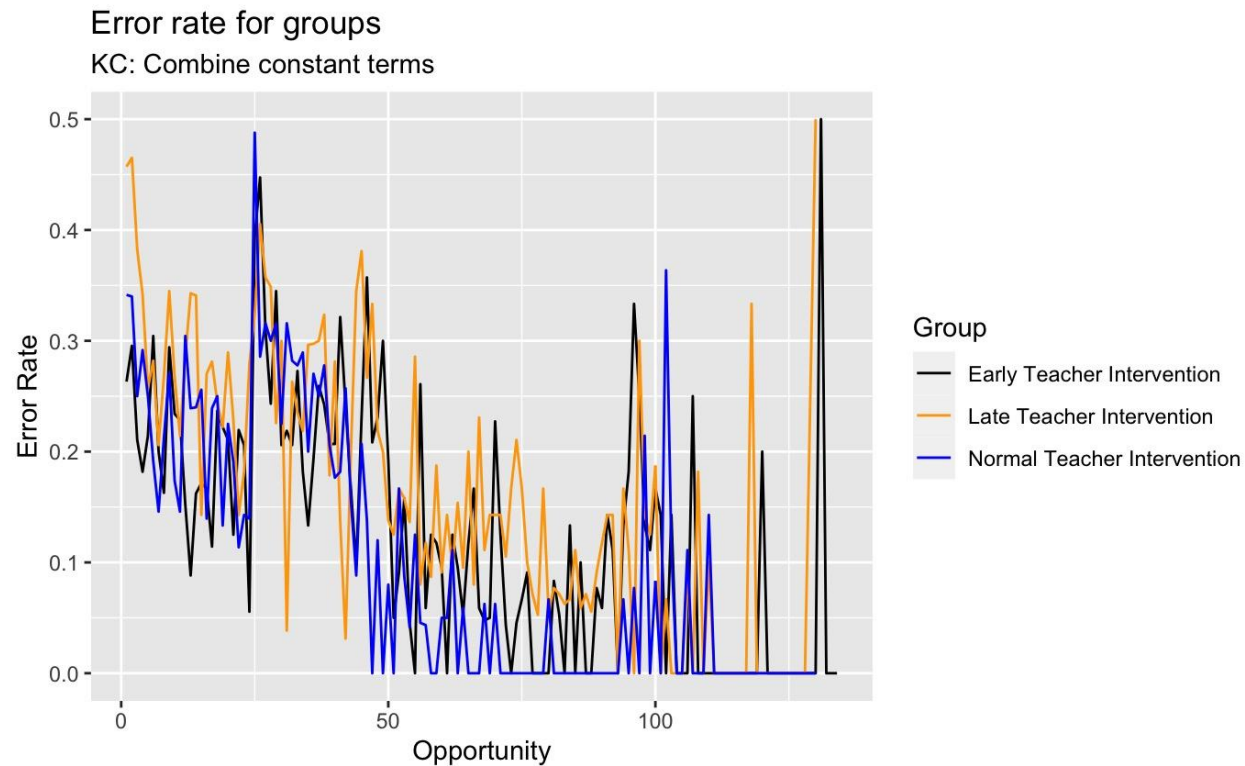
19

Results - Part II

Error rate for groups
KC: Divide both sides by the variable coefficient

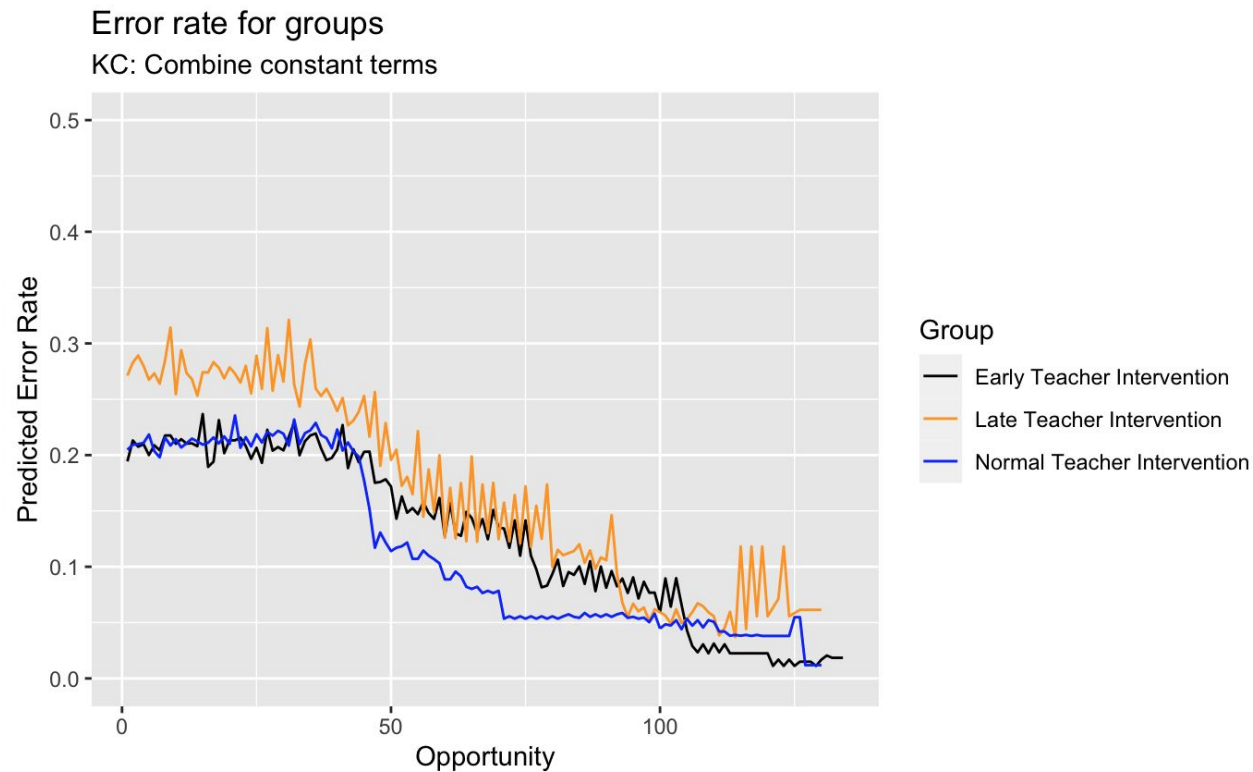
- Predicted error rate (using Group AFM model)
- Three curves
  - Black: error rate for students who received teachers' help in an early stage (opportunity<=4)
  - Blue: error rate for students who received teachers' help in a normal stage (4<opportunity<=11)
  - Orange: error rate for students who received teachers' help in a late stage (opportunity>11)
- Early-intervention group has lower error rate

Results - Part II

Error rate for groups
KC: Combine constant terms

- Raw error rate
- Three curves
  - Black: error rate for students who received teachers' help in an early stage (opportunity<=5)
  - Blue: error rate for students who received teachers' help in a normal stage (5<opportunity<=17)
  - Orange: error rate for students who received teachers' help in a late stage (opportunity>17)

Results - Part II

Error rate for groups
KC: Combine constant terms

- Predicted error rate (using Group AFM model)
- Three curves
  - Black: error rate for students who received teachers' help in an early stage (opportunity<=5)
  - Blue: error rate for students who received teachers' help in a normal stage (5<opportunity<=17)
  - Orange: error rate for students who received teachers' help in a late stage (opportunity>17)
- Early-intervention group has lower error rate

22

Discussion

- Our new AFM model suggests that teachers' intervention is effective at improving students' performance.

- The effectiveness can be measured by the coefficients of our Teacher-indicator and Teacher-Opportunity interaction term.

- Students who get the teacher earlier tend to do better than students who get the teacher late.

  - This may due to the fact that students who receive teacher help early also received more helps during their entire process than students who received teacher help late

- Negative interaction between teacher intervention and opportunity could be the result of the students who perform poorly in this KC transitioning from "Pre-teacher" to "Post-teacher" as the opportunity increases and the subsequent increase in the error rate.

Next Steps

- Large sample size (More students)

- Explore the relationship between the total number of teacher interventions and students' learning rate

- Examine the difference of learning rate between students with teacher interventions and students without teacher interventions using new AFM

Q&A

Thank You