

## Introduction

**OBJECTIVE:** Demonstrate a quasi-experimental method to evaluate the effects of Algebra Nation usage accounting for heterogeneity of usage across Algebra Nation components between users.

Algebra Nation is an example of Open Educational Resource (OER), which are resources that are freely available for use on an ad-hoc basis, allow users flexibility of navigation within the resource, are not tied to a specific curriculum, and do not necessarily provide professional development for instructors.

OER can provide massive datasets, but causal inference about the effectiveness of these systems is complicated by the lack of random assignment of usage and extreme heterogeneity of user behavior in the system.

### RESEARCH QUESTIONS:

1. What are latent classes that summarize the student usage patterns of Algebra Nation?
2. Do the students in different Algebra Nation usage latent classes differ with respect to Algebra I End-of-Course exam scores?
3. Do the differences in Algebra I End-of-Course exam scores between student latent usage classes depend on their previous knowledge of mathematics?

### SAMPLE:

The datasets were obtained from the Florida Department of Education and Algebra Nation, and includes 42,702 students in 602 schools who used the Algebra Nation VLE in the 2016/2017 academic year. The students in the sample were enrolled in Florida schools in grades 6 (1.8%), 7 (11.8%), 8 (42.2%), 9 (46%), and 10 (0.02%).

### STUDENT-LEVEL COVARIATES:

1. Free/reduced lunch eligibility, 2. Ethnicity, 3. Race, 4. FSA Mathematics achievement level

### TEACHER-LEVEL COVARIATES:

5. Years of experience, 6. Certification type, 7. Graduate degree, 8. Mean Login actions, 9. Mean Estimated app time, 10. Mean Video views, 11. Mean test-yourself assessments finished 12. Mean loads of Algebra wall 13. Mean posts to Algebra wall, 14. Mean document views

### SCHOOL-LEVEL COVARIATES:

15. Number of students, 16. Mean scale score EOC previous year 17. Percentage in Level 3 or Above in EOC of previous year

**OUTCOME:** Student scores on the Spring 2017 Algebra 1 End-of-Course assessment.

## Analysis

### Stage 1

#### Latent class analysis of indicators of Algebra Nation usage

- Latent profile analysis was used because all indicators were continuous.

$$f(x_i|\theta) = \sum_1^K \pi_k f_k(x_i|\theta_k)$$

Indicators were transformed: indicator = log(count + 1)

### Stage 2

#### Propensity score weighting

1. Estimation of generalized propensity scores given the set of covariates, accounting for uncertainty of latent classes (Bray, 2018);
2. Calculation of inverse probability weights (Robins, Hernan, & Brumback, 2000) for student classes;
3. Bolck, Croon, and Hagenaars (2004) (BCH) three-step method, improved by Vermunt (2010) was used to account for the uncertainty of class assignment;
4. Evaluation of covariate balance was performed with standardized mean differences;

$$e(X_i, u_i) = \sum_{s=1}^K P(\eta = k|X_i)P(\eta = k|X_i, u_i)$$

Probability of class membership given covariates

Probability of class membership given covariates and class indicators

Multinomial Logistic Regression Model

$$P(\eta = k|X_i) = \frac{\exp(\gamma_{0k} + \sum_{q=1}^Q \gamma_{qk} X_{iq})}{\sum_{s=1}^K \exp(\gamma_{0s} + \sum_{q=1}^Q \gamma_{qs} X_{iq})}$$

Inverse probability of treatment weight

$$W_i = \frac{1}{e(X_i, u_i)}$$

### Stage 3

#### Estimation of treatment effects

- The outcome model was a mixture regression model with cluster-robust standard errors fit with Mplus 8.1, which allowed:
- 1. Estimation of average treatment effect (ATE) of all participants belonging to a class of users versus all participants belong to another class of users
- 2. Estimation of interaction effects with previous mathematics achievement.

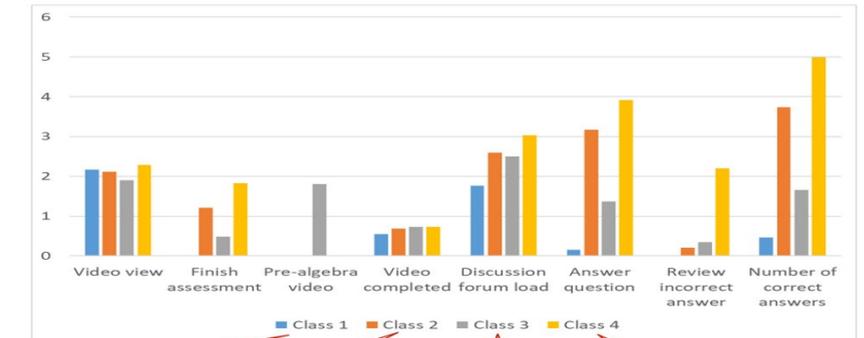
$$y_{ki} = \alpha_k + \beta_{1k} x_{1ki} + \beta_{2k} x_{2ki} + e_{ki}$$

Algebra EOC assessment score

Mathematics FSA score Level 1 and 2

Mathematics FSA score Level 4 and 5

## Results



Focus on watching videos

High use, but do not review incorrect answers

Working on pre-algebra

High users of assessment tool

Comparison of standardized effect sizes between pairs of groups as proposed in Leite (2017, chapter 6)

Pairs:	1 x 2	1 x 3	1 x 4	2 x 3	2 x 4	3 x 4
Maximum	0.01	0.25	0.04	0.25	0.04	0.25

### AVERAGE TREATMENT EFFECTS

Parameters	Estimate	S.E.	Est./S.E.	P-Value
Class 1 Mean score	500.908	0.504	994.568	0.000
Mean Class 2 – Mean Class 1	2.282	0.633	3.608	0.000
Mean Class 3 – Mean Class 1	-0.715	2.202	-0.325	0.745
Mean Class 4 – Mean Class 1	6.034	0.859	7.027	0.000

## Conclusions & Limitation

- Both class 4 (high users) and class 2 (high users that do not review incorrect answers) perform better on the Algebra EOC assessment than Class 1 (video watchers) and Class 3 (Remediation with pre-Algebra videos).
- Significant interaction effect between FSA Mathematics level and Class 3 indicate benefits of remediation with pre-Algebra videos.
- Latent class analysis is a viable method to reduce heterogeneity of VLE usage.
- Quasi-experimental analysis of effects of class membership can be performed with inverse probability of treatment weighting.
- LIMITATIONS:**
  - New method for selecting indicators for latent class analysis has not been evaluated.
  - Zero inflated variables, outliers, non-normal distributions.
  - Teacher-level Algebra Nation usage not included in the analysis.

## Contact

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## References

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