



A Novel Video Recommendation System for Algebra: An Effectiveness Evaluation Study

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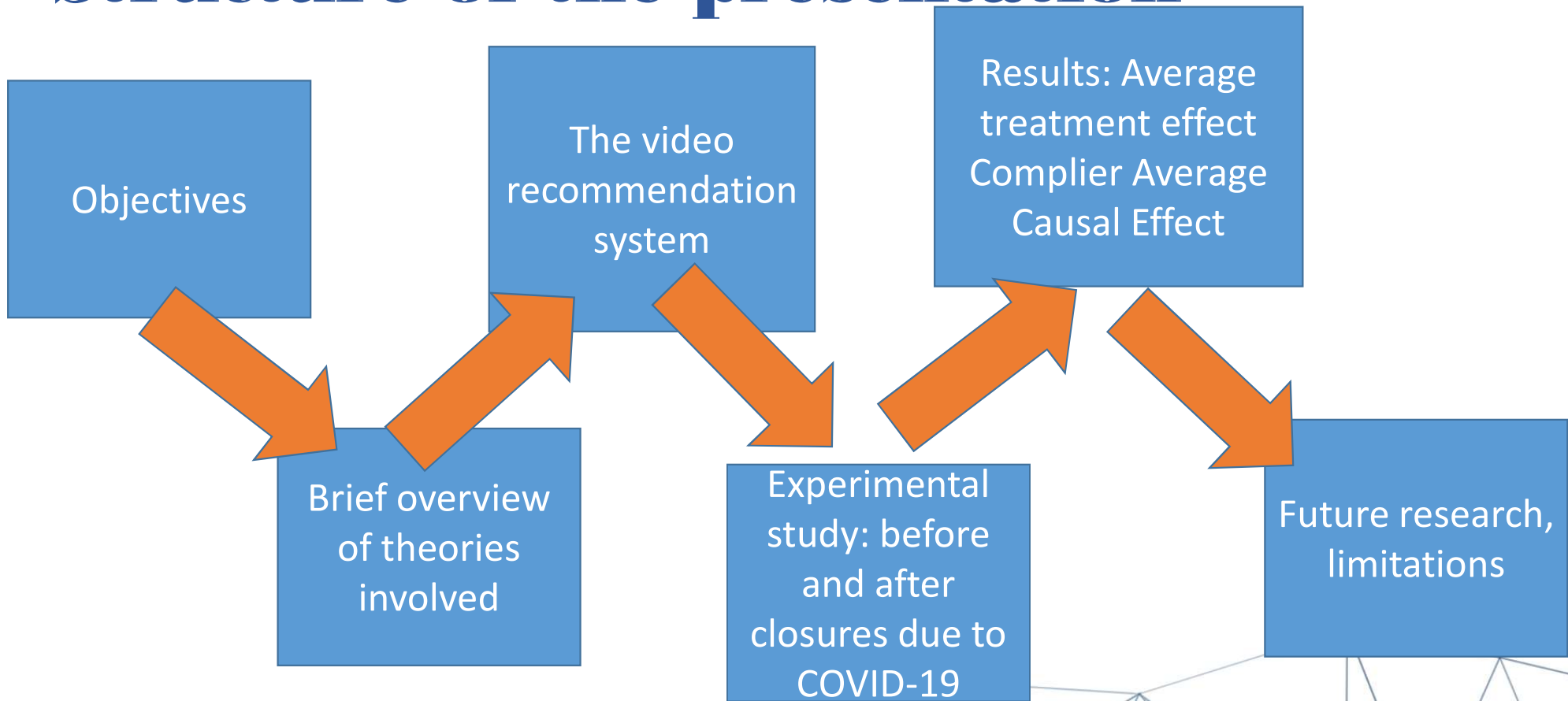
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Structure of the presentation



Objective of the Video Recommendation System

Provide students with a personalized video recommendation that takes into account their current **knowledge** as well as their **engagement** with the system.

Video Recommendation Screen in Math Nation

The screenshot displays the Math Nation interface. A modal window titled "Can we suggest your next video?" is centered on the screen. The modal contains a video thumbnail with the text "RECOMMENDED" and a math problem: $9x^3 + 5x^2 - 5x^3$. Below the thumbnail, there are four multiple-choice questions: b. What is the degree of the polynomial? (7), c. How many terms are in the polynomial? (3), and d. What is the leading term? (What is the coefficient?). A "CLOSE" button is located at the bottom of the modal. In the background, a table shows the results of three questions, all marked as incorrect with a red "X" and the text "TRY AGAIN!". At the bottom of the screen, a blue banner reads "★ YOU GOT 0 OF OUT 3! ★".

QUESTIONS	RESULTS
Question 1	✗ TRY AGAIN!
Question 2	✗ TRY AGAIN!
Question 3	✗ TRY AGAIN!

★ YOU GOT 0 OF OUT 3! ★

Context: Math Nation

The screenshot shows the 'ALGEBRA 1 WALL' section of the Math Nation website. At the top, there are navigation tabs for 'VIDEOS & MORE', 'ALGEBRA 1 WALL', 'LEADERBOARD', and 'EDGE XL'. A 'CALCULATOR' button is visible in the top right. The main content area is titled 'Section 1: Expressions' and includes a 'Welcome to Math Nation!' message and a list of users: Amy, Ashley, Darnell, Jose, Kiana, and Zach. Below this is a 'HELP ME CHOOSE' button and a 'Check Your Understanding' link. The main list of topics includes:

- Section 1 Pretest (Students Only)
- Expressions in a New York Minute
- Section 1: Expressions (Workbook)
- Topic 1: Using Expressions to Represent Real-World Situations (page 3) ✓
- Topic 2: Properties of Exponents (page 6) ✓
- Topic 3: Operations with Rational and Irrational Numbers (page 9) ✓
- Topic 4: Radical Expressions and Expressions with Rational Exponents (page 12) ✓
- Topic 5: Adding Expressions with Radicals and Rational Exponents (page 14) □
- Topic 6: More Operations with Radicals and Rational Exponents (page 16) □
- Topic 7: Understanding Polynomial Expressions (page 19) ✓
- Topic 8: Operations with Polynomials - Part 1 (page 22) ✓
- Topic 9: Operations with Polynomials - Part 2 (page 23) ✓
- Section 1 Test Yourself! Practice Tool
- Section 1 Posttest (Students Only)
- Section 2: Equations and Inequalities
- Section 3: Introduction to Functions
- Section 4: Linear Equations, Functions and Inequalities
- Section 5: Quadratic Functions - Part 1
- Section 6: Quadratic Functions - Part 2
- Section 7: Exponential Functions
- Section 8: Summary of Functions

The screenshot shows a question page titled 'Question 1 of 3'. It includes a 'Back to Videos' button and a 'NEXT QUESTION >' button. The question text is: 'Consider the following rectangle:'. Below the text is a diagram of a rectangle with a height of $4\sqrt{20} + 2\sqrt{24}$ and a width of $3\sqrt{8}$. The question asks: 'Select all expressions that are equivalent to the perimeter of the rectangle.' Below the question is a horizontal line for an answer and a list of options:

- $3\sqrt{8} + 4\sqrt{20} + 2\sqrt{24}$
- $2(3\sqrt{8} + 4\sqrt{20} + 2\sqrt{24})$
- $2(3\sqrt{8}) + 2(4\sqrt{20} + 2\sqrt{24})$
- $12\sqrt{2} + 16\sqrt{5} + 8\sqrt{6}$
- $12^{\frac{1}{2}} + 16^{\frac{1}{2}} + 8^{\frac{1}{2}}$

Theoretical Background

- ▶ Vygotsky's theory of Zone of Proximal Development
- ▶ D'Mello, Dieterle and Duckworth's advanced, analytic, automated (AAA) approach to measure engagement for interactions with digital learning technologies
- ▶ Item Response Theory

The algorithm for new videos

ALGORITHM 1. New Video Recommendation Policy for Student i

Inputs: initial ability estimates $\{a_{ij}(0)\}$, $1 \leq i \leq n, 1 \leq j \leq r$.

Output: sequence of recommended videos $\hat{j}(t) \in \{1, \dots, r\}, t \geq 0$

for $t = 0, 1, \dots$ **do**

 Compute peer ability-estimates

$$b_j(t) = n^{-1} \sum_{i=1}^n a_{ij}(t).$$

 Compute the probability distribution $\{p_j(t)\}, j = 1, 2, \dots, r$,

$$p_j(t) = \frac{\exp[-w_j(a_{ij}(t) - b_j(t))]}{\sum_{j=1}^r \exp[-w_j(a_{ij}(t) - b_j(t))]}.$$

 Sample $\hat{j}(t)$ from the distribution $\{p_j(t)\}, 1 \leq j \leq r$.

 Read $\{a_{ij}(t+1)\}, 1 \leq i \leq n, 1 \leq j \leq r$ from the database.

end for

The video recommendation system

Five categories of video recommendation:

- 1) View new video;
- 2) Review current topic video with a new tutor;
- 3) Review segment of current video with current tutor;
- 4) Review segment of current video with a new tutor;
- 5) View next video in curriculum sequence.

CYU score	Engagement Threshold	Probability of Recommendation of Category C
0	< 3.5	$p(C=1) = 0.7$ $p(C=2) = 0.3$
0	≥ 3.5	$p(C=1) = 0.3$ $p(C=2) = 0.7$
1	< 3.5	$p(C=1) = 0.3$ $p(C=4) = 0.7$
1	≥ 3.5	$p(C=1) = 0.3$ $p(C=3) = 0.7$
2	Any	$p(C=3) = 1$
3	Any	$p(C=5) = 1$

Research Questions

- ▶ Did the students, who were offered video recommendations perform better on the post-test assessments than the students who were not offered such recommendations?
- ▶ What is the causal effect of video recommendations on the achievement of those students who watched the recommended videos when offered?

Field Experiment

- Three large school districts in Florida:
 - ◇ 18,925 students from 152 teachers in 149 schools
- ▶ The study lasted for 17 weeks during the Spring 2020 semester (i.e., February 3rd to May 31st)
- ▶ Transition on March 17th when all schools were closed due to the COVID-19 pandemic and instruction resumed online.

Average Treatment Effects (Intention to Treat)

	Before school closure			After school closure		
	Coefficient	SE	p-value	Coefficient	SE	p-value
(Intercept)	-0.752	0.176	0.000	-0.339	0.602	0.573
ITT	0.054	0.027	0.043	-0.009	0.030	0.775
Pretest	-0.012	0.040	0.764	0.025	0.112	0.825
Engagement	-0.021	0.022	0.349	-0.007	0.028	0.805

Complier Average Causal Effect

- ▶ Before schools closed, the proportion of compliers among the students who were assigned to the treatment group was = 0.15921, SE = 0.0188, CI = [0.122, 0.196].
- ▶ Before-closure period, the final CACE standardized estimate is 0.34 (SE = 0.17, $p = 0.043$)
- ▶ After schools closed, the proportion of compliers was = 0.1123, SE = 0.0112, CI = [0.090, 0.134].
- ▶ The CACE was not statistically significant for the period after schools closed (CACE = -0.076, SE = 0.266, $p = 0.775$).

Where do we go from here?

- ▶ Completed a longer replication of the experiment (November 24th 2020 to June 1st 2021) to be presented at L@S 2022
- ▶ Key questions:
 - Are the effects larger with a longer exposure?
 - Do students who use the system more extensively benefit more?
 - Are there certain groups of students who benefit more?
 - Are there certain teaching strategies that moderate the impact of the video recommendation system?
 - What are the fairness and equity implications of personalization?