Analyzing SCALE Data to Identify Learning Outcome Mastery in Precalculus

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FN5 Summer Research Program
Mathematics: Statistics
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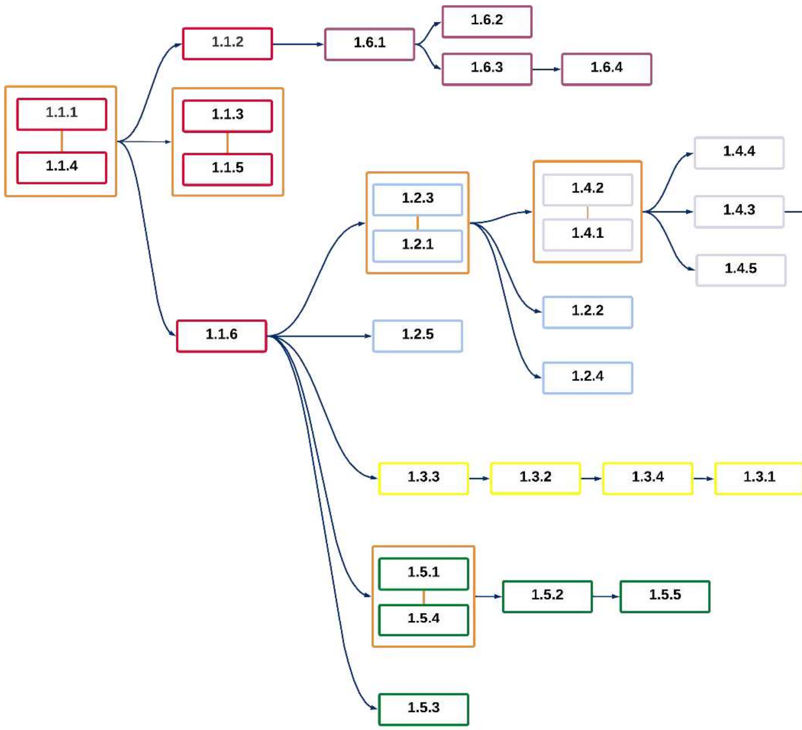
Background

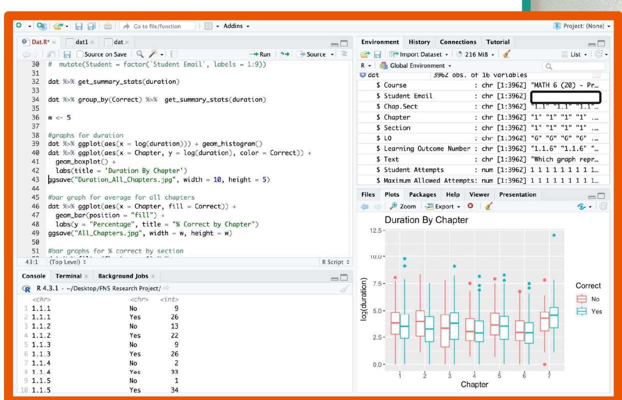
- $1 Million - California Education Learning Lab "Innovation" grant
  - ***Goal #1****: Transform the culture of learning in math classrooms*
  - ***Goal #2****: **Develop and utilize suitable Adaptive Learning Technology** and appropriate pedagogy to assist students of all backgrounds.*
  - ***Goal #3****: Improve the learning outcomes and close the achievement gaps among student populations*
- Focus on College Algebra and Precalculus
- Student-Centered Adaptive Learning Environment (**SCALE**)
  - Developed by Dr. Cecotti and students of the CS Department at Fresno State.
  - ***"A platform for delivering adaptive instruction online, and provides a framework that guides the learner through the instructional content based on proven theories about how people learn effectively."***

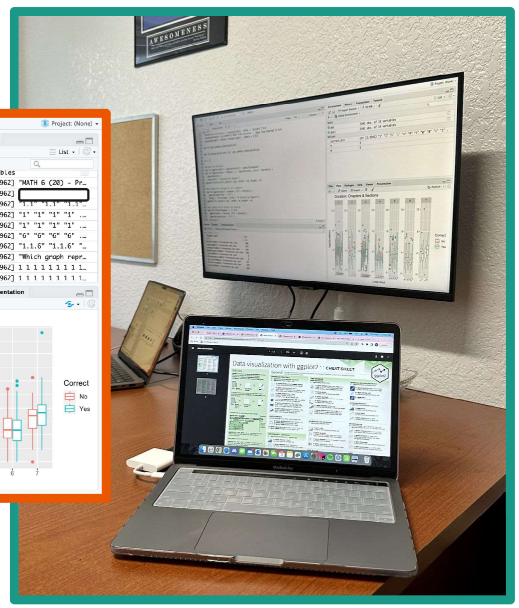


PreCalculus Chapter 1 - Functions

Color	Section	LO #	Section Title	Learning Outcome
	1.1	1.1.1	Functions and Function Notation	Determining Whether a Relation Represents a Function
	1.1	1.1.2	Functions and Function Notation	Finding Input and Output Values of a Function
	1.1	1.1.3	Functions and Function Notation	Determining Whether a Function is One-to-One
	1.1	1.1.4	Functions and Function Notation	Using the Vertical Line Test
	1.1	1.1.5	Functions and Function Notation	Using the Horizontal Line Test
	1.1	1.1.6	Functions and Function Notation	Identifying Basic Toolkit Functions
	1.2	1.2.1	Domain and Range	Finding the Domain of a Function Defined by an Equation
	1.2	1.2.2	Domain and Range	Using Notations to Specify Domain and Range
	1.2	1.2.3	Domain and Range	Finding Domain and Range from Graphs
	1.2	1.2.4	Domain and Range	Finding Domains and Ranges of the Toolkit Functions
	1.2	1.2.5	Domain and Range	Graphing Piecewise-Defined Functions
	1.3	1.3.1	Rates of Change and Behavior of Graphs	Finding the Average Rate of Change of a Function
	1.3	1.3.2	Rates of Change and Behavior of Graphs	Using a Graph to Determine Where a Function is Increasing, Decreasing, or Constant
	1.3	1.3.3	Rates of Change and Behavior of Graphs	Analyze the Toolkit Functions for Increasing or Decreasing Intervals
	1.3	1.3.4	Rates of Change and Behavior of Graphs	Use A Graph to Locate the Absolute Maximum and Absolute Minimum
	1.4	1.4.1	Composition of Functions	Combining Functions Using Algebraic Operations
	1.4	1.4.2	Composition of Functions	Create a Function by Composition of Functions
	1.4	1.4.3	Composition of Functions	Evaluating Composite Functions
	1.4	1.4.4	Composition of Functions	Finding the Domain of a Composite Function
	1.4	1.4.5	Composition of Functions	Decomposing a Composite Function into its Component Functions
	1.5	1.5.1	Transformation of Functions	Graphing Functions Using Vertical and Horizontal Shifts
	1.5	1.5.2	Transformation of Functions	Graphing Functions Using Reflections about the Axes
	1.5	1.5.3	Transformation of Functions	Determining Even and Odd Functions
	1.5	1.5.4	Transformation of Functions	Graphing Functions Using Stretches and Compressions
	1.5	1.5.5	Transformation of Functions	Performing a Sequence of Transformations
	1.6	1.6.1	Absolute Value Functions	Understanding Absolute Value
	1.6	1.6.2	Absolute Value Functions	Graphing an Absolute Value Function
	1.6	1.6.3	Absolute Value Functions	Solving an Absolute Value Equation
	1.6	1.6.4	Absolute Value Functions	Solving an Absolute Value Inequality
	1.7	1.7.1	Inverse Functions	Verifying That Two Functions Are Inverse Functions
	1.7	1.7.2	Inverse Functions	Finding Domain and Range of Inverse Functions
	1.7	1.7.3	Inverse Functions	Finding and Evaluating Inverse Functions
	1.7	1.7.4	Inverse Functions	Finding Inverse Functions and Their Graphs

Part 1: Research Tools





- ➢ All research was done on a laptop!
- ➢ R is among a few different programming languages that are used for statistical computing and graphics.
- ➢ Familiarizing with the R language and its applications.

Part 2: The Dataset

- ➢ Have a fundamental understanding of the source.
- ➢ Categorical vs. numerical variables
    - ○ String, images/video, date/time, etc.
- ➢ *Tidy* Format

Learning Outcome Number	Text
1.1.6	Which graph represents the `f(x)=x^2` function?
1.1.6	Which graph represents the `f(x)=|x|` function?
1.1.6	Which graph represents the `f(x)=sqrt(x)` function?
1.1.6	Which graph represents the `f(x)=1/x` function?
1.1.6	Which equation represents the following graph and ta...
1.3.3	State the interval(s) on which the function `f(x)=x^2`...
1.3.3	State the interval(s) on which the function `f(x)=1/x`

```
#>       country year fertility
#> 1     Germany 1960      2.41
#> 2 South Korea 1960      6.16
#> 3     Germany 1961      2.44
#> 4 South Korea 1961      5.99
#> 5     Germany 1962      2.47
#> 6 South Korea 1962      5.79
```

```
#>       country 1960 1961 1962
#> 1     Germany 2.41 2.44 2.47
#> 2 South Korea 6.16 5.99 5.79
```

Source: Irizarry, R. A. (2020). The tidyverse. In *Introduction to data science: Data analysis and prediction algorithms with R*. essay, CRC Press.

Part 3: Data Cleaning

- ➢ Determining and extracting relevant information from raw data.
- ➢ Combining, separating, and filtering the data to create new useful variables for each observations.

```
#splitting the 'Learning Outcome Number' column into ch
#dat %<>% separate(col = `Learning Outcome Number`,
#                  into = c("Chapter", "Section", "LO"),
#                  remove = FALSE)
```

Learning Outcome Number	Chapter	Section	LO
1.1.6	1	1	6
1.1.6	1	1	6
1.1.6	1	1	6
1.1.6	1	1	6
1.1.6	1	1	6
1.3.3	1	3	3
1.3.3	1	3	3
1.3.3	1	3	3
1.7.1	1	7	1
1.7.1	1	7	1
2.1.2	2	1	2

```
#creating columns
#dat %<>%
#  mutate(correct_binary = c(correct_bin), .after = `Correct`) %>%
#  mutate(duration = as.numeric(`Date Time Answered` - `Date Time Started`)) %>%
#  mutate(Student = factor(`Student Email`, labels = 1:7))
```

Date Time Started	Date Time Answered	duration	Student
2023-06-14 09:25:11	2023-06-14 09:25:16	5	4
2023-06-14 09:25:19	2023-06-14 09:25:24	5	4
2023-06-14 09:25:26	2023-06-14 09:25:31	5	4
2023-06-14 09:25:33	2023-06-14 09:25:53	20	4
2023-06-14 09:25:56	2023-06-14 09:26:59	63	4
2023-06-18 18:10:56	2023-06-18 18:11:26	30	4
2023-06-18 18:11:40	2023-06-18 18:11:54	14	4
2023-06-18 18:11:55	2023-06-18 18:12:07	12	4
2023-06-19 19:50:30	2023-06-19 19:54:19	229	4
2023-06-19 19:56:26	2023-06-19 19:56:29	3	4
2023-06-21 15:01:57	2023-06-21 15:02:06	9	4
2023-06-21 15:02:06	2023-06-21 15:02:10	4	4

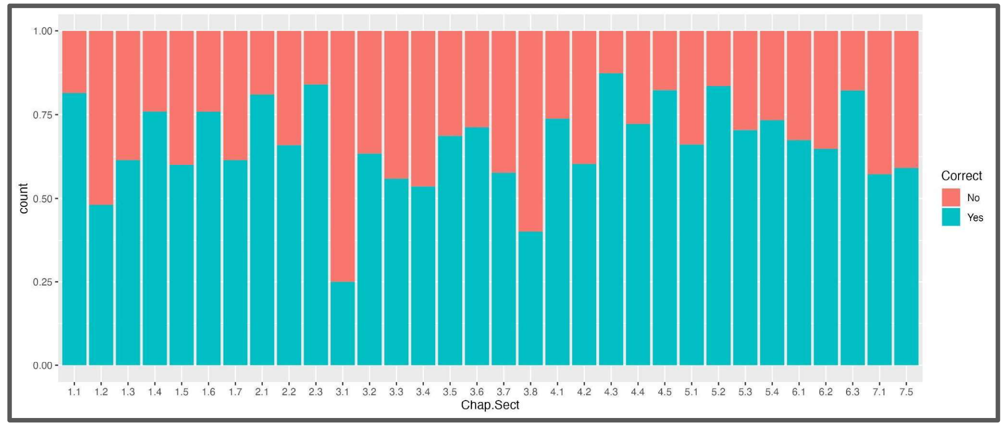
- ➢ R have the capability to use operation on variables.
- ➢ It can also re-assign values to existing variables.

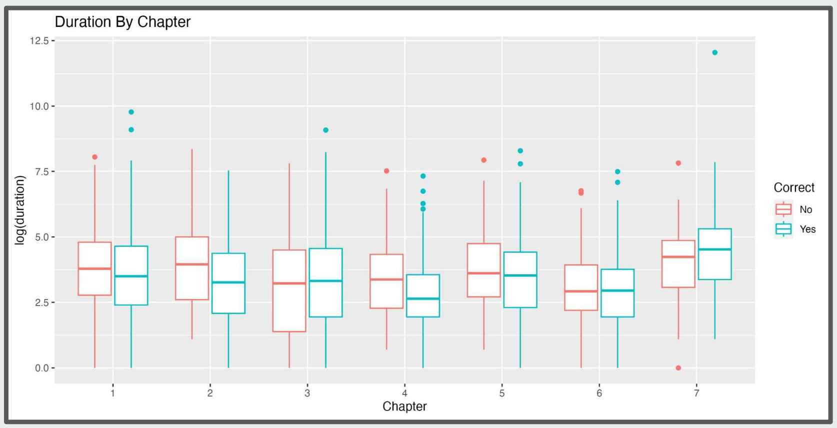
Part 4: Exploratory Data Analysis

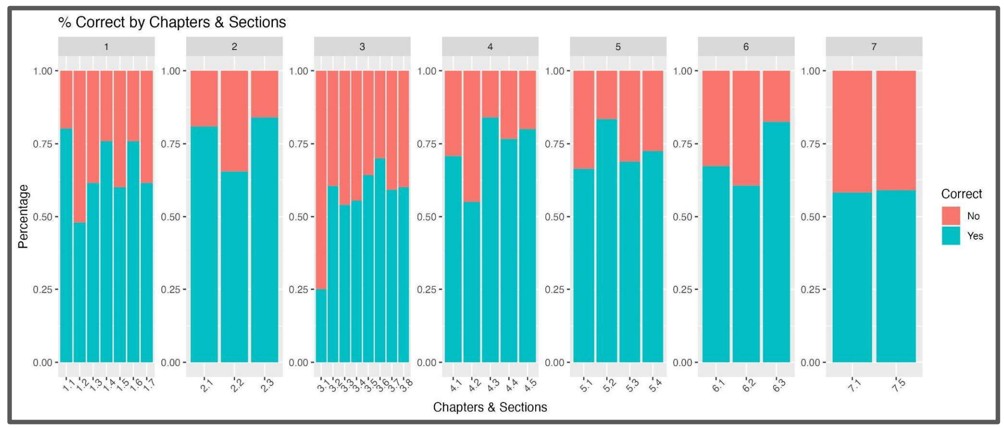
- Noting trends and inconsistencies from data
- Comparing different qualities and graphs.
- How can the data be used to improve SCALE and math education for students?

Visualizing Data

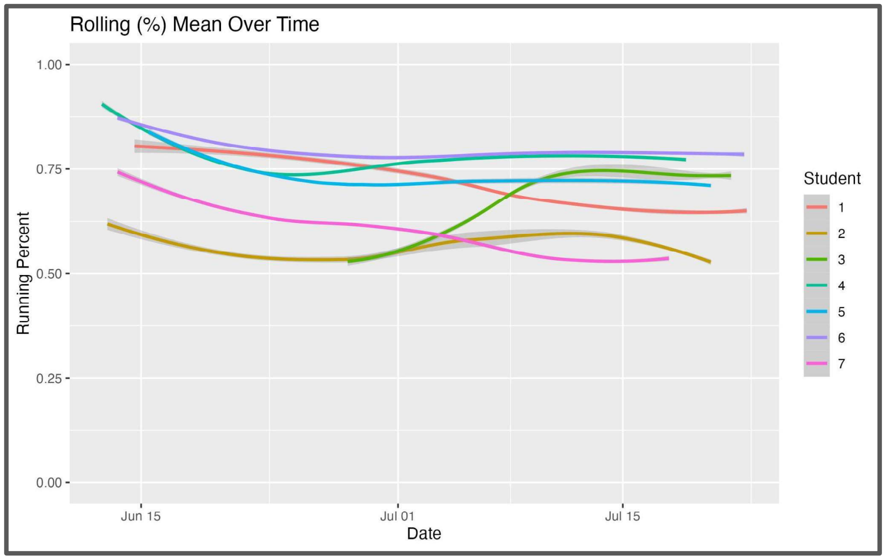
➢ R is a powerful and versatile tool that can construct an extensive range of graphs.

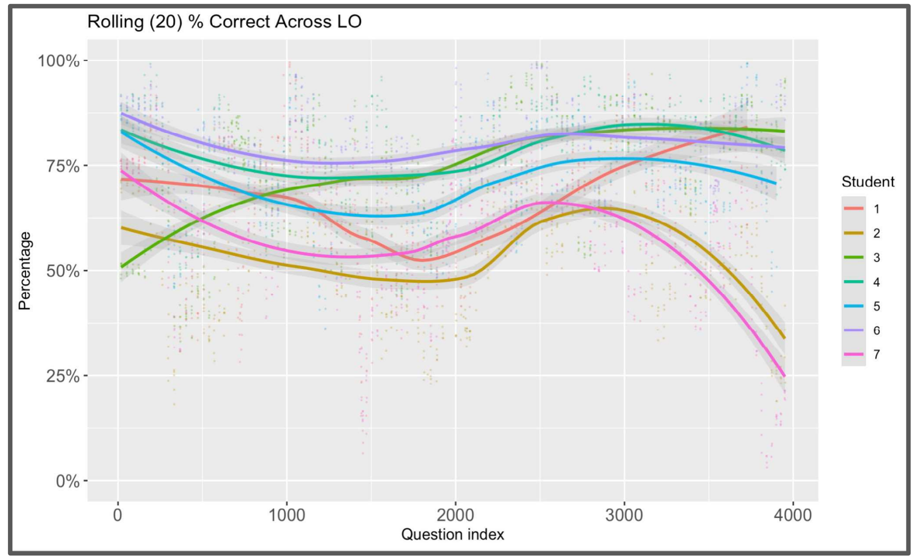




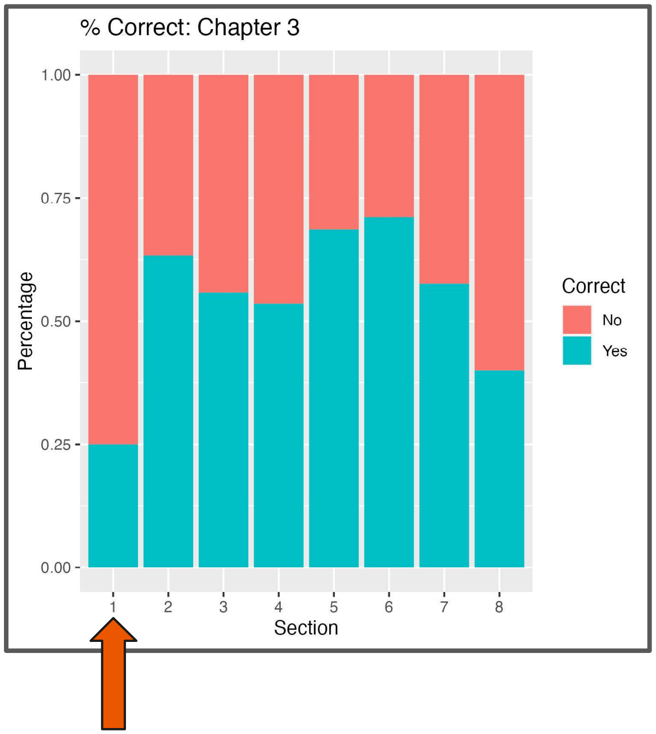


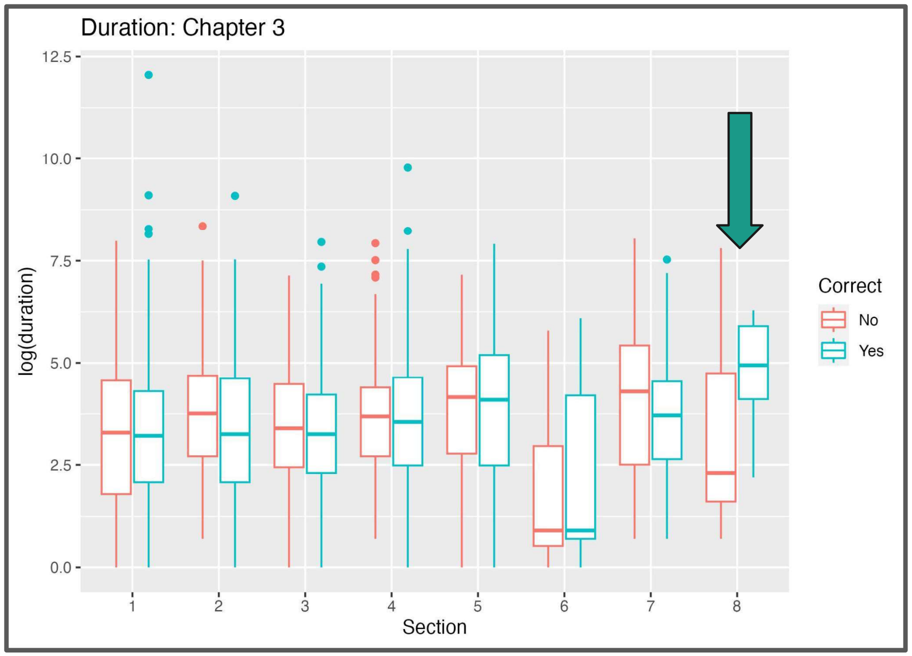
Tracking Students' Progress



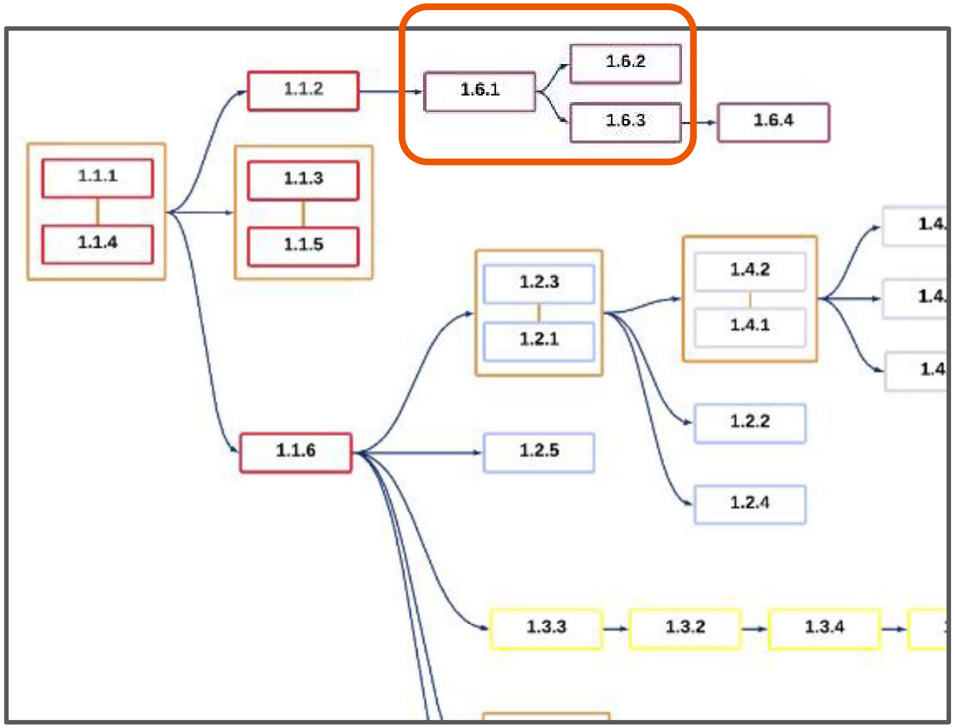


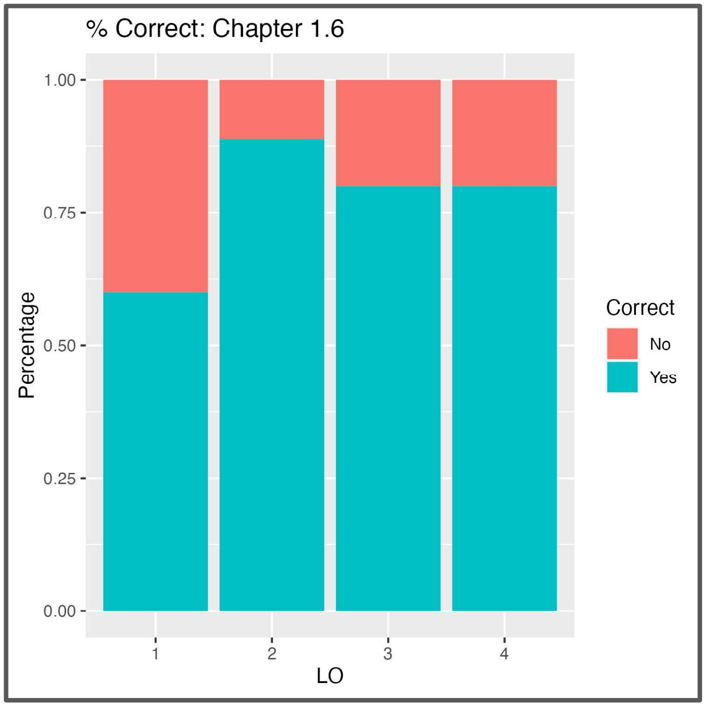
Isolating Difficult Checkpoints





Identifying Abnormal Learning Outcomes





Future Considerations?

- Text mining
- Exam scores and final grades
- Bigger sample over a longer period of time

Acknowledgements

- California Education Learning Lab
- The On-Ramp to STEM project
  - Dr. Amarasinghe (PI) and Dr. Balderama (Co-PI)
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LEARNING LAB

California OR2STEM

FRESNO STATE College of Science and Mathematics