

# Revealing Undergraduate biology students' conceptions of variability within graphing

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## Highlights

The bar graph a student makes reflects their basic understanding of variability and understanding of what data error bars represent in a bar graph

Answer confidence in describing error bars increased for students who also graphed using error bars

## Background

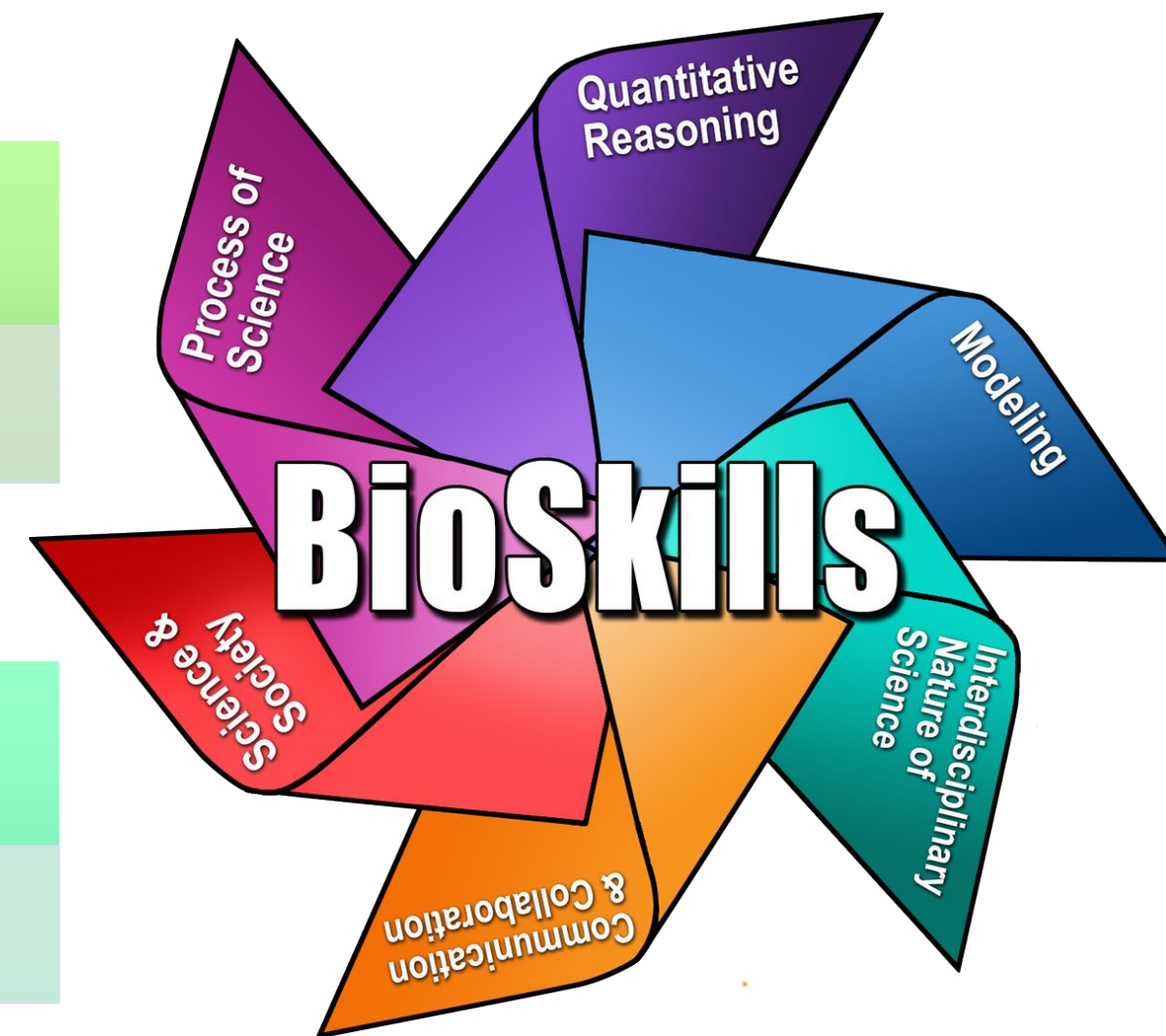
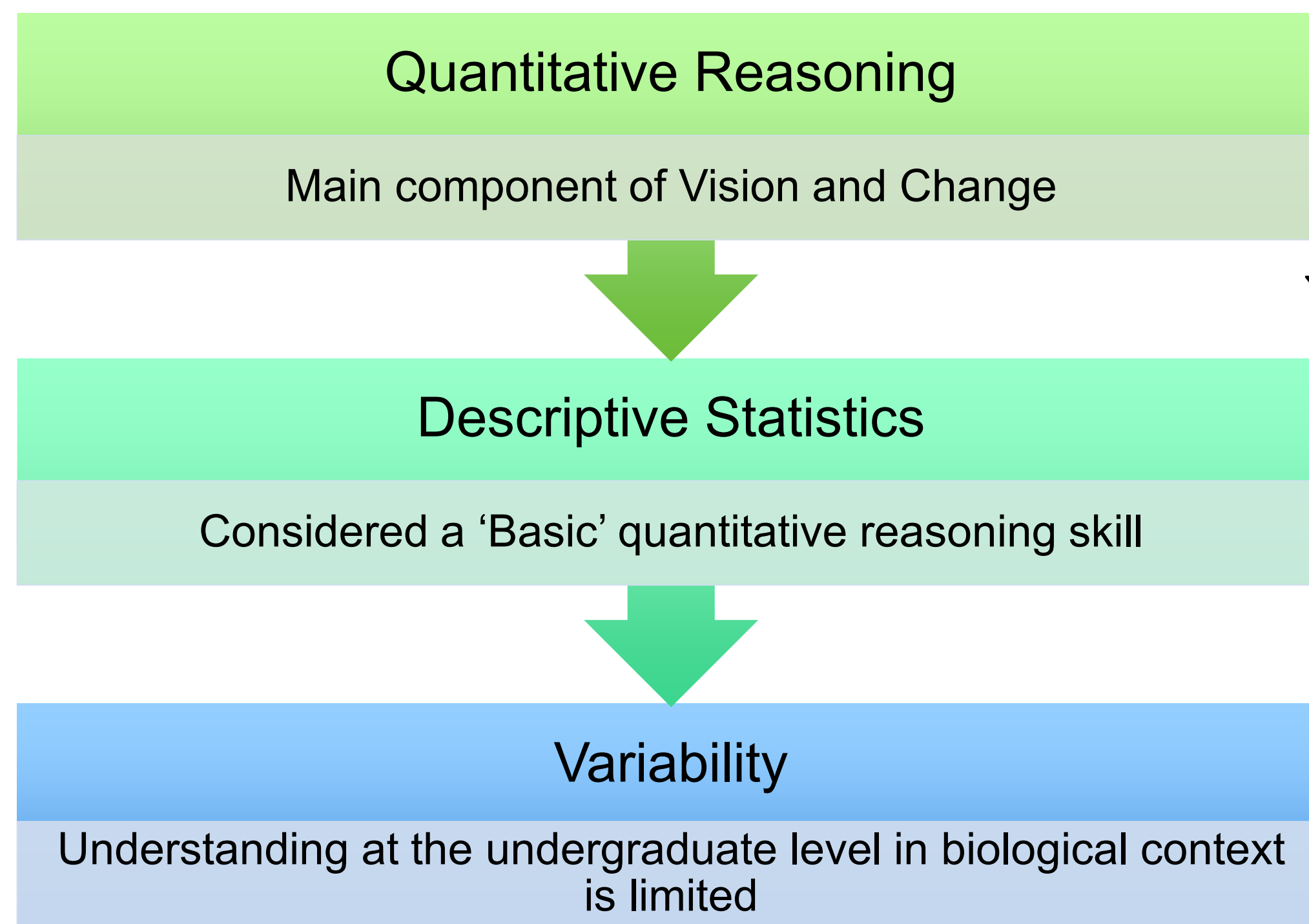


Figure 1: Course level learning objectives for general biology students and the skills they should have acquired by graduation.

## Overview of main categories from students explaining what data error bars represent

**Broad Terms**- Students use over arching terms such as variability and uncertainty to explain error bars

**Terms of Error**- Students discuss error bars showing general error, error in the data, error in experimentation, or discuss error bars in describing accuracy or precision.

**Purpose**- Students discuss different purposes for error bars such as representing standard deviation, standard error, confidence intervals, outliers, distribution, range, and/or use for making predictions.

**Trend and Analysis**- Students discuss ways error bars are used for analyzing trends such as using error bar size or overlap. Error bars could be used as a test. Discussing error bars representing the distance from the mean. Recognizing that the bar represents the mean within the graph. Talking about general comparisons between treatments on the graph.

Scan to download a copy of the codebook with definitions and example quotes



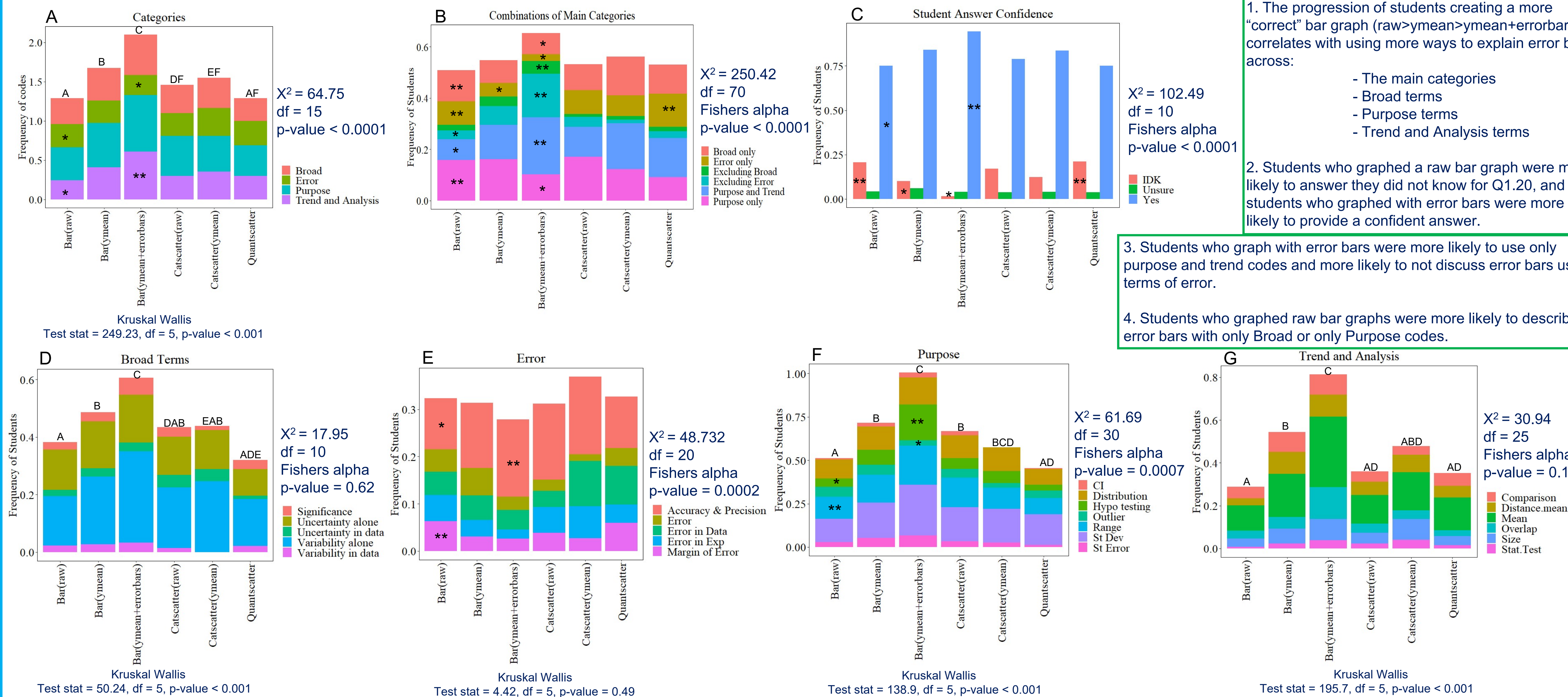
## How does the graph a student makes predict their understanding of interpreting variability within a treatment.



### Main Takeaways

- There is a progression of understanding from students who graph raw data on a bar graph to students who graph means and use error bars on their bar graphs- All but Graph 3.
- In Graph 3- students who made categorical scatterplots showing all the data found these graph easier to interpret
- In Graph 4, students who used error bars were more likely to identify that variability was not shown.

## How does the graph a student makes predict their explanation of the data error bars represent on a bar graph.



### Main Takeaways

- The progression of students creating a more "correct" bar graph (raw>yemean>errorbars) correlates with using more ways to explain error bars across:
  - The main categories
  - Broad terms
  - Purpose terms
  - Trend and Analysis terms
- Students who graphed a raw bar graph were more likely to answer they did not know for Q1.20, and students who graphed with error bars were more likely to provide a confident answer.
- Students who graph with error bars were more likely to use only purpose and trend codes and more likely to not discuss error bars using terms of error.
- Students who graphed raw bar graphs were more likely to describe error bars with only Broad or only Purpose codes.

Figure 3: Frequency with which students use codes to describe what error bars represent on a bar graph. Graphs A and B look broadly across the main categories. Graph C looks at students answer confidence. Graphs D – G look at detailed codes within each of the main categories. Significantly lower frequency by chance is shown by \* and significantly higher than by chance is shown by \*\* based on residuals from chi-square analyses. Total codes used was analyzed using a Kruskal Wallis test and post hoc Dunn test. Significant differences are shown using letters at the top of the bars.

## Research Questions

For data disaggregated based on student graph construction

- How does the graph a student makes predict their understanding of interpreting variability within a treatment.
- How does the graph a student makes predict their explanation of the data error bars represent on a bar graph.

## Methods

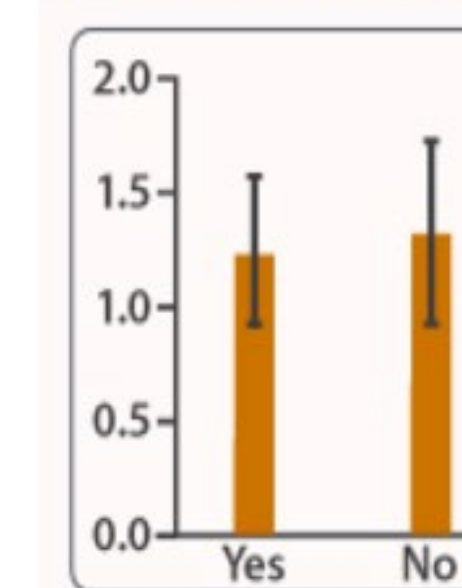
**GraphSmarts:** Performance based graphing assessment which has students create graphs and interpret variability. We have six different scenarios students may have completed.

- Performed deductive and inductive thematic coding on Q1.20; N=3506
- Conducted analysis on quantitative responses from Q1.16; N=3506
- Responses are from a variety of institutions intro or upper division courses: R1, R2, Masters granting, PUI, and Community Colleges

### Graph student made for a prediction that required a categorical variable and quantitative variable for a correct graph

Bar graph (raw)	1071
Bar graph (ymean)	484
Bar graph (ymean + errorbars)	391
Quant scatter – Student chose at least one incorrect variable	184
Catscatter (raw)	205
Catscatter (ymean)	73

Q1.20. The image below shows a bar graph with error bars. What type of information do the error bars provide you about the data represented in each bar? If you are unsure, please respond with "I do not know".



Choices include:

- Easy to interpret
- Hard to interpret
- Variability not shown
- I'm not sure

