ADVANCED STATISTICS

EFFECTS ON LEARNING OF SMALL CLASS SIZES

An Analytical Study

INTRODUCTION

EFFECT OF CLASS SIZE

Whether small classes really help with learning.

DEMOGRAPHIC FACTORS

Which sex/race benefits the most from the implemented schemes.

RESOURCE ALLOCATION

Cost of implementation of these schemes in general schools.

ANALYSIS

Visual and statistical means to figure out the effect of various factors on learning.

THE DATASET

FOR EACH STUDENT

CLASS TYPES

Description of the class the student is in. They are either regular, regular with aid, or smaller classes.

SCORES

Scaled scores for Math and Reading were provided for each student. These were the metrics for performance.

DEMOGRAPHIC

These fields described the sex and race of the students in the study.

TEACHER EXPERIENCE

The dataset had teachers with experiences ranging from 1 to 27 years.

FREE LUNCH SCHEME

Some students, from lower financial backgrounds availed the free lunch scheme at their school.

EXPLORATORY DATA ANALYSIS

RACE DISTRIBUTION

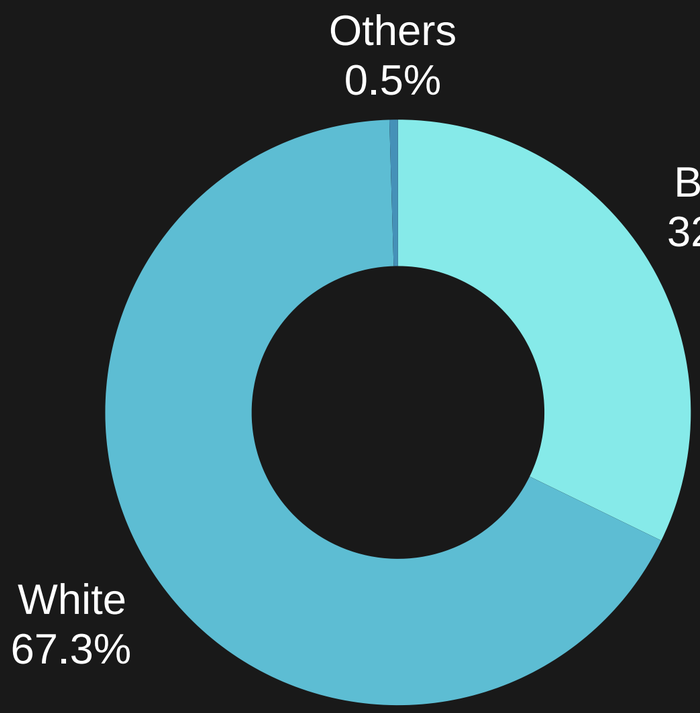
CLASS SIZE EFFECT ON PERFORMANCE

EXPERIENCE EFFECT ON PERFORMANCE

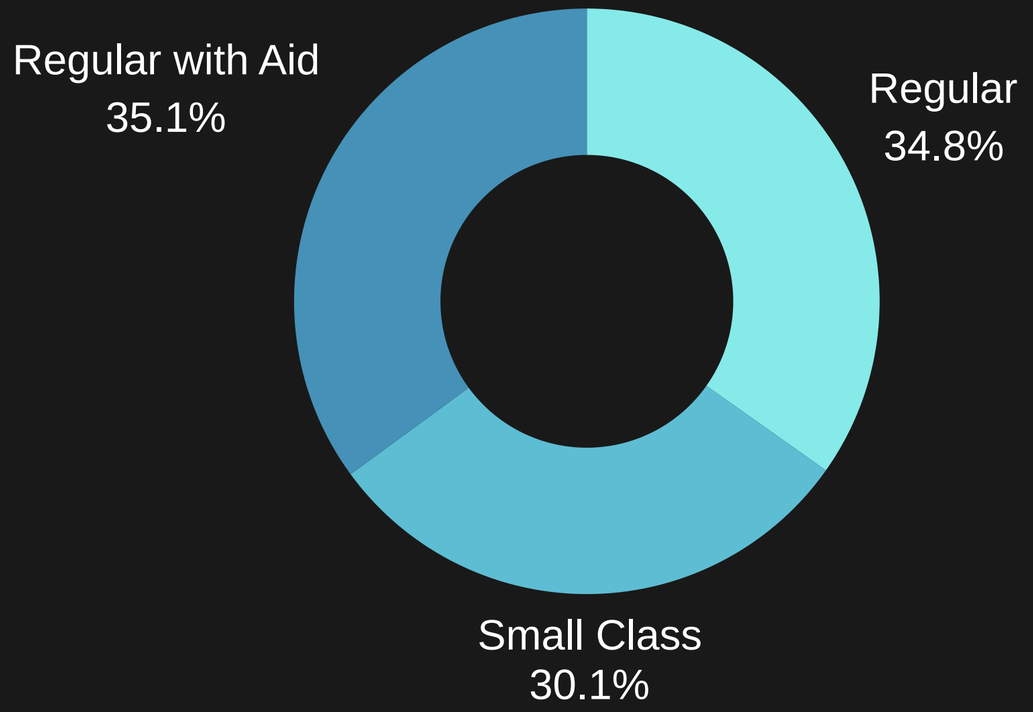
CLASS SIZE DISTRIBUTION

RACE EFFECT ON PERFORMANCE

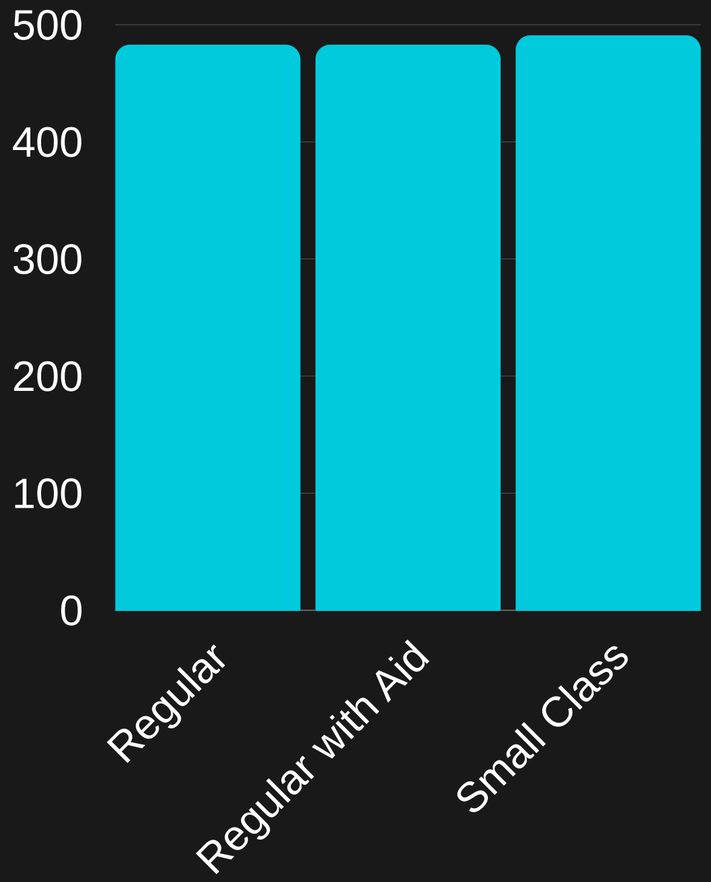
FINANCE EFFECT ON PERFORMANCE



RACE DISTRIBUTION



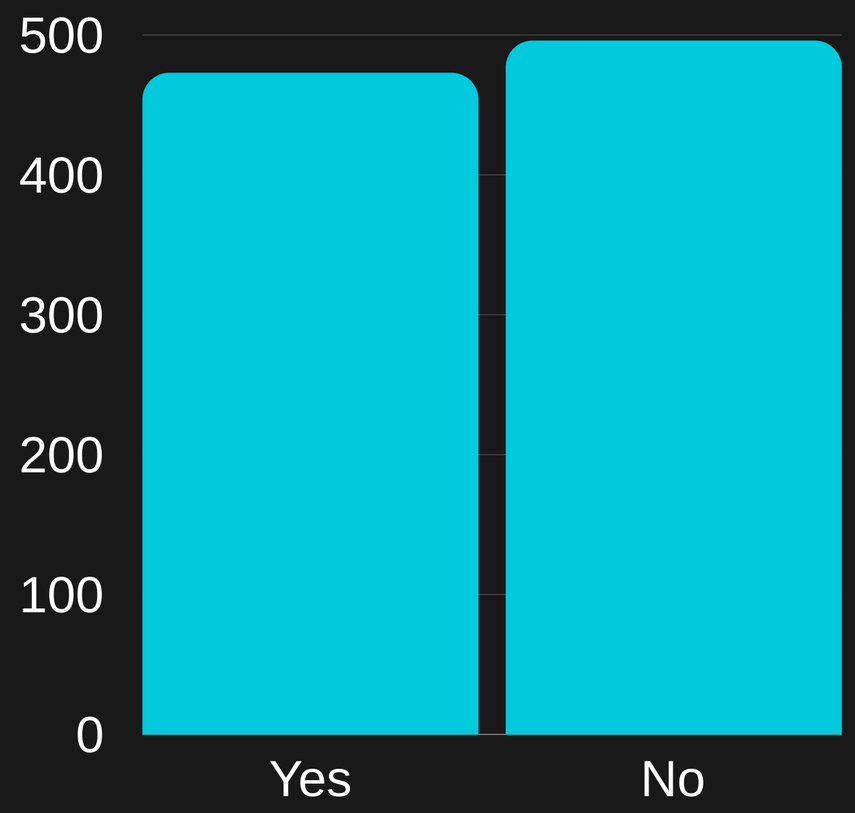
CLASS DISTRIBUTION



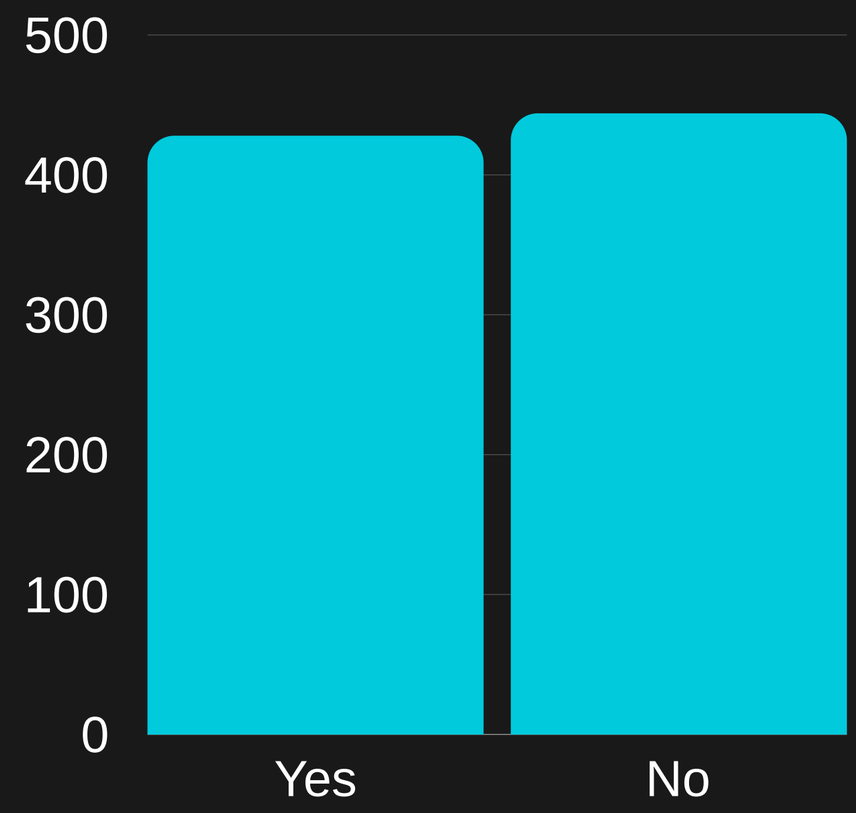
MATH SCORES

READING SCORES

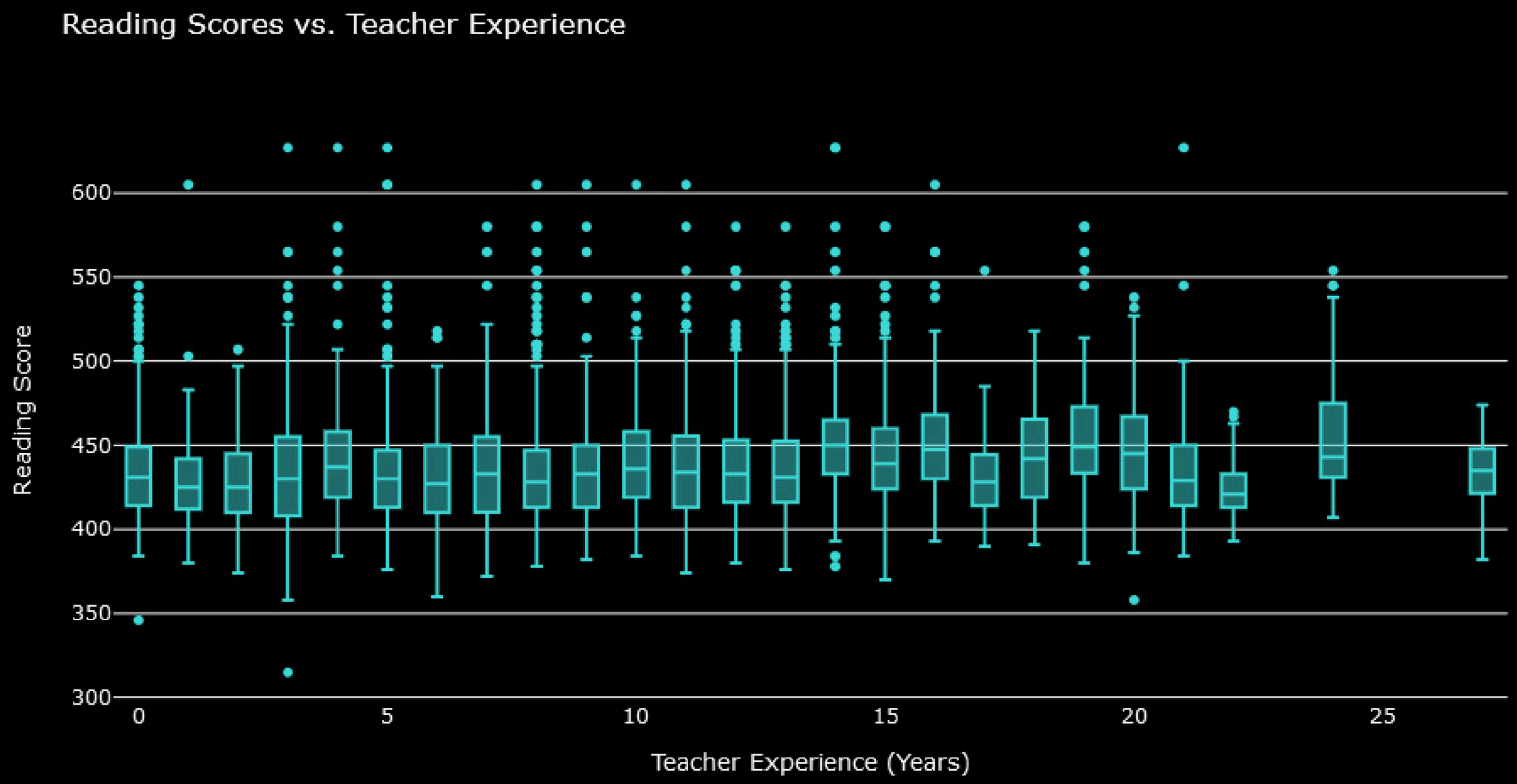
AVAILING FREE LUNCH SCHEME

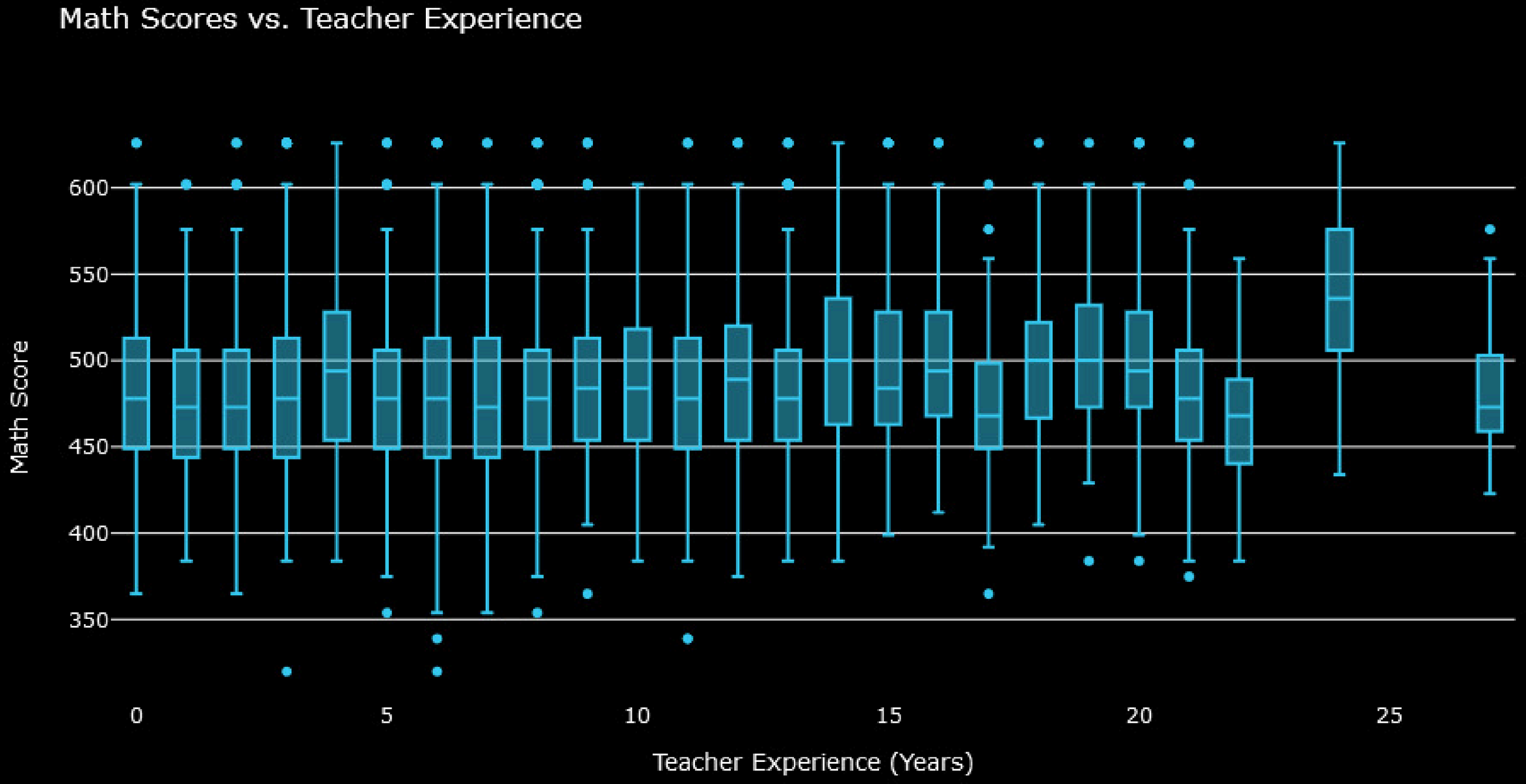


MATH SCORES



READING SCORES


Reading Scores vs. Teacher Experience
Reading Score
600
550
500
450
400
350
300
0
5
10
15
20
25
Teacher Experience (Years)


Math Scores vs. Teacher Experience
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Teacher Experience (Years)

HYPOTHESIS TESTING

ADVANCED STATISTICS

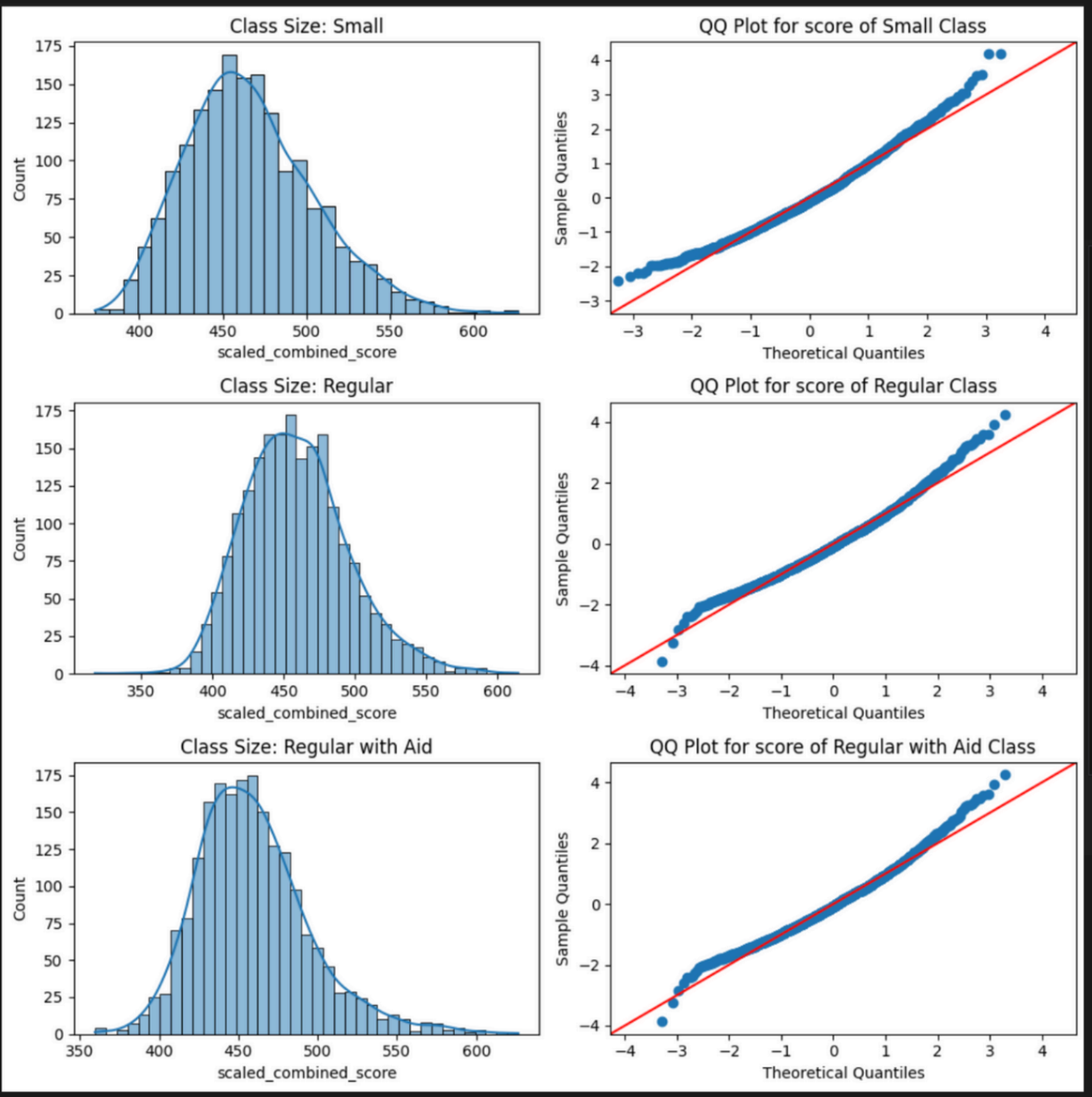
NULL HYPOTHESIS

THERE IS NO STATISTICALLY SIGNIFICANT DIFFERENCE IN ACADEMIC PERFORMANCE ATTRIBUTABLE TO VARIATIONS IN CLASS SIZES

	df	sum_sq	mean_sq	F	PR(>F)
class_type	2.0	5.796135e+04	28980.676432	21.390791	5.552856e-10
Residual	5745.0	7.783442e+06	1354.820215	NaN	NaN

```
          Multiple Comparison of Means - Tukey HSD, FWER=0.05
=============================================================================
      group1            group2      meandiff p-adj lower  upper  reject
-----------------------------------------------------------------------------
          regular regular.with.aide   0.2776 0.969 -2.446 3.0013  False
          regular       small.class   7.0544   0.0 4.2225 9.8862   True
regular.with.aide       small.class   6.7768   0.0 3.9498 9.6037   True
-----------------------------------------------------------------------------
```

- ACADEMIC PERFORMANCE IS THE COMBINED MATH AND READING SCORE.
- THERE IS STATISTICAL DIFFERENCE BETWEEN THE ACADEMIC PERFORMANCE BETWEEN THE THREE CLASS SIZES.
- THE SMALL CLASS SIZES PERFORM BETTER THAN THE OTHER TWO.




```python
from scipy.stats import levene

# Perform Levene's test
statistic, p_value = levene(df[df['class_type'] == 'small.class']['scaled_combined_score'],
                            df[df['class_type'] == 'regular']['scaled_combined_score'],
                            df[df['class_type'] == 'regular.with.aide']['scaled_combined_score']
                            )

# Display the results
print(f"Statistic: {statistic}")
print(f"P-value: {p_value}")

# The null hypothesis of Levene's test is that the variances are equal across all groups.
# A small p-value suggests that there is evidence to reject the null hypothesis, indicating
# that at least one group has a different variance.
```

✓ 0.0s

```
Statistic: 7.266342070923406
P-value: 0.000705102773581642
```

DATA IS NORMALLY DISTRIBUTED, INDEPENDENT OF ONE ANOTHER, BUT THE VARIANCES ARE NOT EQUAL.

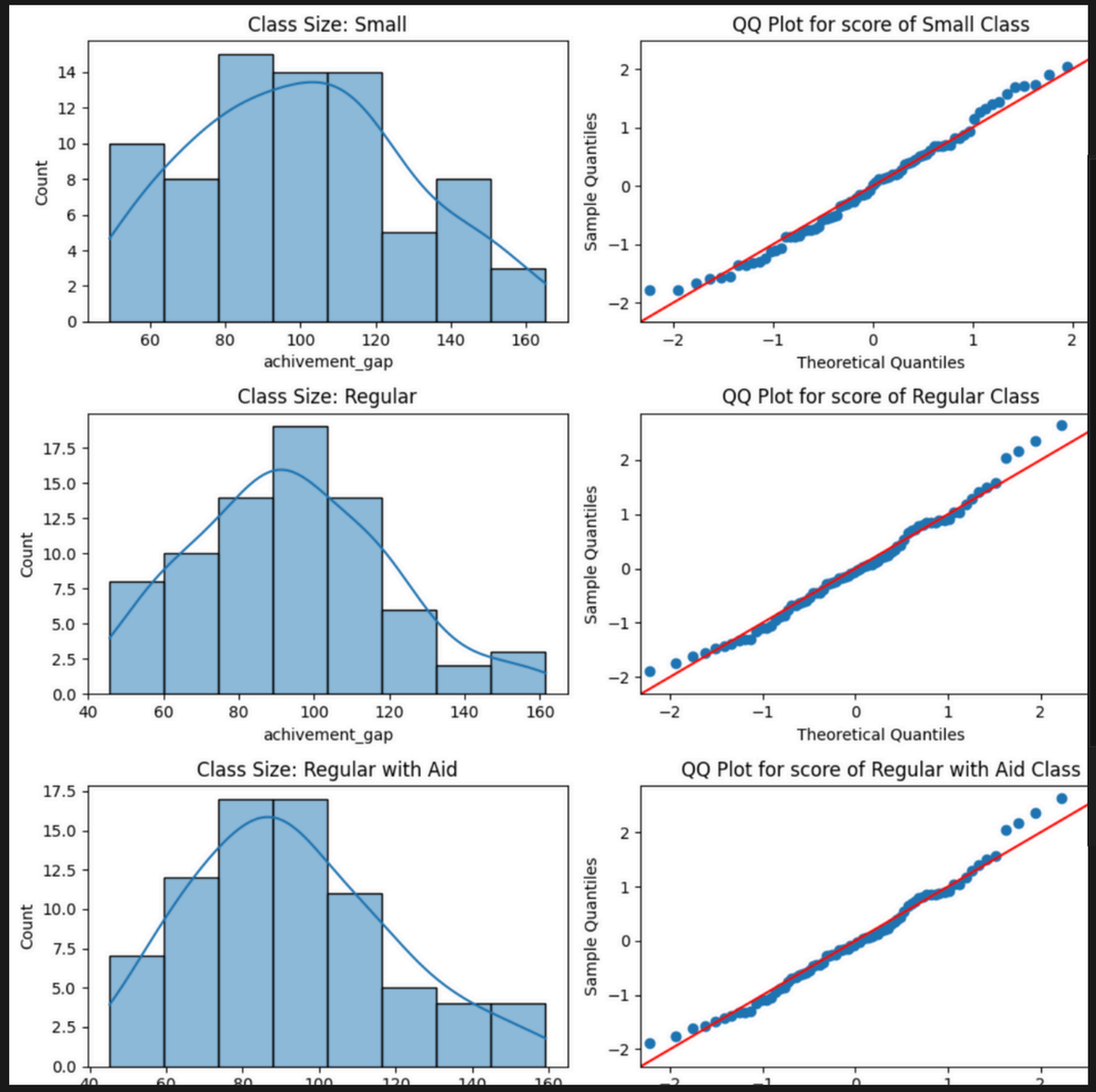
NULL HYPOTHESIS

THERE IS NO STATISTICALLY SIGNIFICANT DIFFERENCE IN ACHIEVEMENT GAP ATTRIBUTABLE TO VARIATIONS IN CLASS SIZES

	df	sum_sq	mean_sq	F	PR(>F)
class_type	2.0	2422.410083	1211.205042	1.664353	0.191615
Residual	227.0	165195.480796	727.733396	NaN	NaN

```
          Multiple Comparison of Means - Tukey HSD, FWER=0.05
=============================================================================
      group1            group2      meandiff p-adj   lower    upper  reject
-----------------------------------------------------------------------------
          regular regular.with.aide  -1.2441 0.9562 -11.5348  9.0465  False
          regular       small.class   6.1663 0.3355  -4.1244 16.4569  False
regular.with.aide       small.class   7.4104 0.2057  -2.8466 17.6674  False
-----------------------------------------------------------------------------
```

- ACHIEVEMENT GAP IS THE DIFFERENCE IN THE MEAN COMBINED SCORES OF THE TOP 10 PERFORMERS AND THE BOTTOM 10 PERFORMERS.
- THERE IS NO STATISTICAL DIFFERENCE BETWEEN THE ACHIEVEMENT GAP BETWEEN THE THREE CLASS SIZES.
- THE TOP PERFORMERS IN EACH CLASS SIZE ARE EQUALLY AHEAD OF THE BOTTOM PERFORMERS IN EACH CLASS.




```
from scipy.stats import levene

# Perform Levene's test
statistic, p_value = levene(achivement_gap_df[achivement_gap_df['class_type
                            achivement_gap_df[achivement_gap_df['class_type
                            achivement_gap_df[achivement_gap_df['class_type
                            )

# Display the results
print(f"Statistic: {statistic}")
print(f"P-value: {p_value}")

# The null hypothesis of Levene's test is that the variances are equal acro
# A small p-value suggests that there is evidence to reject the null hypoth
# that at least one group has a different variance.
```

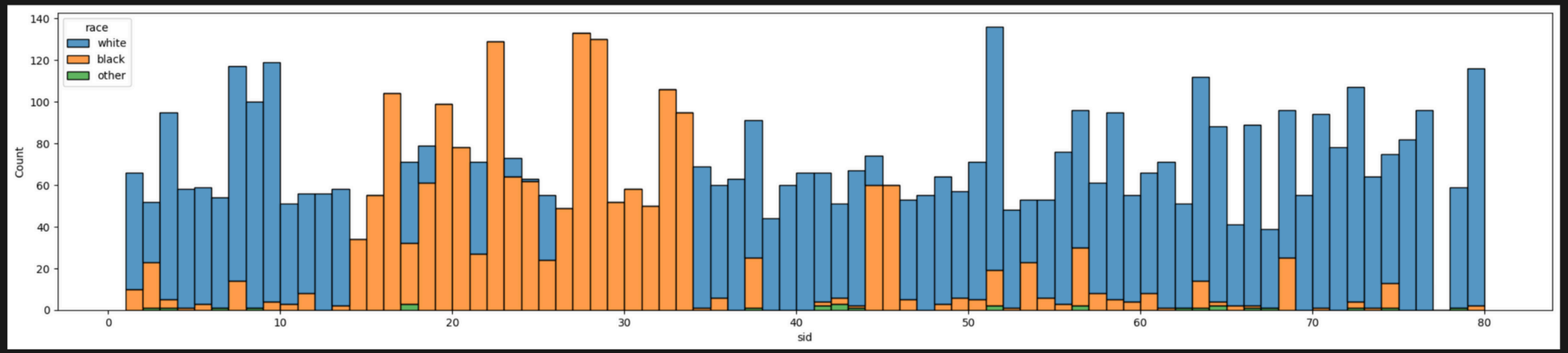
✓ 0.0s

```
Statistic: 0.9033267965949597
P-value: 0.4066708894820553
```

DATA IS NORMALLY DISTRIBUTED, INDEPENDENT OF ONE ANOTHER, AND THE VARIANCES ARE EQUAL.

NULL HYPOTHESIS

THERE IS NO STATISTICALLY SIGNIFICANT DIFFERENCE IN ACADEMIC PERFORMANCE ATTRIBUTABLE TO VARIATIONS IN MAJORITARIAN RACE



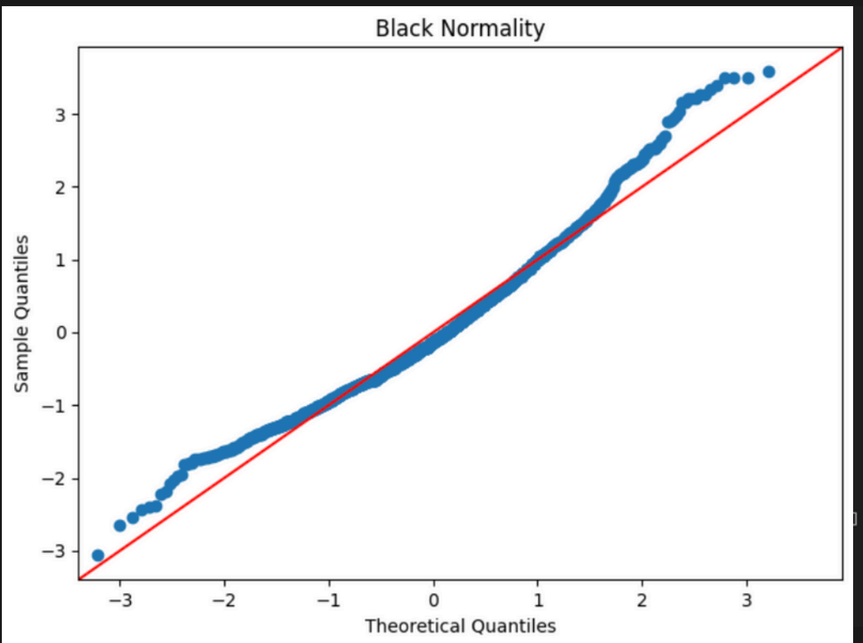
ADVANCED STATISTICS

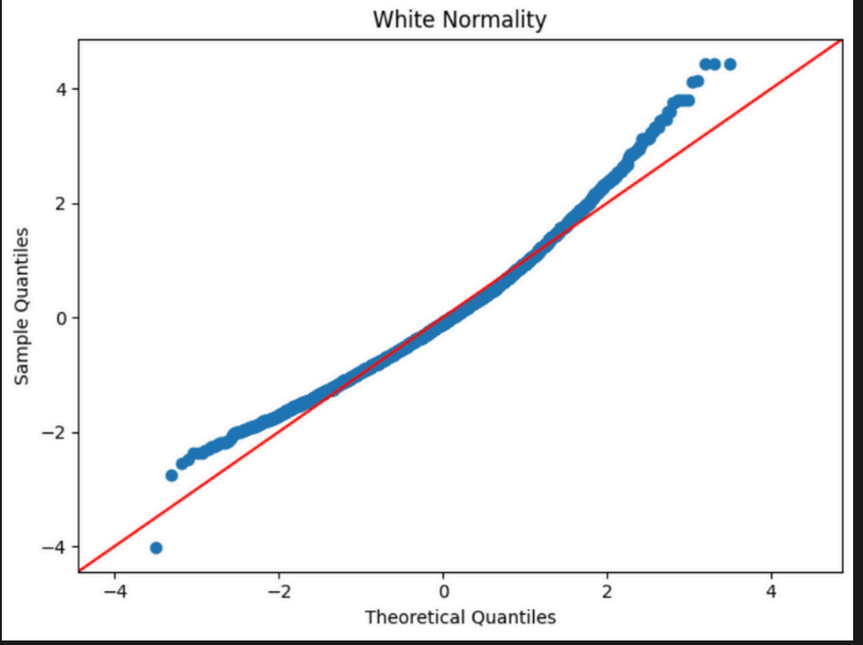
	df	sum_sq	mean_sq	F	PR(>F)
dominant_race	1.0	1.367009e+05	136700.908922	101.948572	8.987480e-24
Residual	5746.0	7.704703e+06	1340.881061	NaN	NaN

```
T-statistic: -10.096958533319205
P-value: 8.987479506901872e-24
The difference between the two groups is statistically significant.

The mean score of students from black dominant is 453.0654174884944 and white dominant is 464.12053465815
```

- **THERE IS STATISTICALLY SIGNIFICANT DIFFERENCE BETWEEN THE ACADEMIC PERFORMANCE BETWEEN THE SCHOOLS THAT ARE WHITE DOMINATED AND THE ONES THAT ARE BLACK DOMINATED.**
- **WHITE DOMINATED SCHOOLS GENERALLY PERFORM BETTER.**






```python
from scipy.stats import levene

# Perform Levene's test
statistic, p_value = levene(df[df['dominant_race'] == 'white']['scaled_combined_score'], df[df[

# Display the results
print(f"Statistic: {statistic}")
print(f"P-value: {p_value}")

# The null hypothesis of Levene's test is that the variances are equal across all groups.
# A small p-value suggests that there is evidence to reject the null hypothesis, indicating
# that at least one group has a different variance.
```

✓ 0.0s

```
Statistic: 0.691365464461825
P-value: 0.40573487467891167
```

- DATA IS RIGHT SKEWED NORMALLY DISTRIBUTED.
- VARIANCE IN TOTAL SCORE OF WHITE DOMINANT AND BLACK DOMINANT SCHOOLS ARE SIMILAR.

NULL HYPOTHESIS

THERE IS NO STATISTICALLY SIGNIFICANT INTERACTION BETWEEN THE EFFECT OF CLASS SIZE ON VARIOUS DEMOGRAPHICS LIKE RACE, SEX, AND FINANCIAL BACKGROUND

TWO WAY ANOVA

- EFFECT ON COMBINED SCORE BY CLASS TYPE AND RACE
- EFFECT ON COMBINED SCORE BY CLASS TYPE AND SEX
- EFFECT ON COMBINED SCORE BY CLASS TYPE AND AVAILING OF FREE LUNCH SCEME

NO INTERACTION BETWEEN CLASS TYPE AND RACE

	sum_sq	df	F	PR(>F)
C(class_type)	5.463163e+04	2.0	20.864192	9.366554e-10
C(race)	2.679669e+05	2.0	102.338382	2.134023e-44
C(class_type):C(race)	1.861682e+03	4.0	0.355494	8.403538e-01
Residual	7.513614e+06	5739.0	NaN	NaN

NO INTERACTION BETWEEN CLASS TYPE AND AVAILING FREE LUNCH

	sum_sq	df	F	PR(>F)
C(class_type)	5.397023e+04	2.0	21.485562	5.054530e-10
C(free_lunch)	5.715789e+05	1.0	455.091364	3.072137e-97
C(class_type):C(free_lunch)	1.118483e+02	2.0	0.044527	9.564502e-01
Residual	7.211751e+06	5742.0	NaN	NaN

STATISTICALLY SIGNIFICANT INTERACTION BETWEEN CLASS TYPE AND SEX

	sum_sq	df	F	PR(>F)
C(class_type)	5.799640e+04	2.0	21.632525	4.368492e-10
C(sex)	6.874993e+04	1.0	51.287141	8.981350e-13
C(class_type):C(sex)	1.759474e+04	2.0	6.562798	1.422544e-03
Residual	7.697097e+06	5742.0	NaN	NaN

GIRLS AND BOYS PERFORM SIMILARLY IN SMALL CLASS SIZES

```
small_class_girl_score = df[(df["class_type"] == "small.class") & (df['sex'] == 'girl')]["scaled_combined_score"]
small_class_boy_score = df[(df["class_type"] == "small.class") & (df['sex'] == 'boy')]["scaled_combined_score"]

t_statistic, p_value = ttest_ind(small_class_girl_score, small_class_boy_score)

print(f'T-statistic: {t_statistic}')
print(f'P-value: {p_value}')

# Interpret the results
alpha = 0.01  # significance level
if p_value < alpha:
    print("The difference between the two groups is statistically significant.")
else:
    print("There is no statistically significant difference between the two groups.")

print(f"\nThe mean score for girls in small class {small_class_girl_score.mean()} and for boys in small class is {small_class_boy_score.mean()}")
```

✓ 0.0s Python

```
T-statistic: 1.8597357003421364
P-value: 0.06309246068571991
There is no statistically significant difference between the two groups.

The mean score for girls in small class 467.78028503562945 and for boys in small class is 464.36700336700335
```

GIRLS PERFORM BETTER IN REGULAR CLASS SIZES

```python
regular_class_girl_score = df[(df["class_type"] == "regular") & (df['sex'] == 'girl')]["scaled_combined_score"]
regular_class_boy_score = df[(df["class_type"] == "regular") & (df['sex'] == 'boy')]["scaled_combined_score"]

t_statistic, p_value = ttest_ind(regular_class_girl_score, regular_class_boy_score)

print(f'T-statistic: {t_statistic}')
print(f'P-value: {p_value}')

# Interpret the results
alpha = 0.01  # significance level
if p_value < alpha:
    print("The difference between the two groups is statistically significant.")
else:
    print("There is no statistically significant difference between the two groups.")

print(f"\nThe mean score for girls in regular class {regular_class_girl_score.mean()} and for boys in regular class is {regular_class_boy_score.mean()}")
```

✓ 0.0s Python

```
T-statistic: 7.176771428293762
P-value: 1.0017674896636543e-12
The difference between the two groups is statistically significant.

The mean score for girls in regular class 464.9326131687243 and for boys in regular class is 453.3341439688716
```

GIRLS PERFORM BETTER IN REGULAR CLASS SIZES WITH AID

```python
regular_with_aid_class_girl_score = df[(df["class_type"] == "regular.with.aide") & (df['sex'] == 'girl')]["scaled_combined_score"]
regular_with_aid_class_boy_score = df[(df["class_type"] == "regular.with.aide") & (df['sex'] == 'boy')]["scaled_combined_score"]

t_statistic, p_value = ttest_ind(regular_with_aid_class_girl_score, regular_with_aid_class_boy_score)

print(f'T-statistic: {t_statistic}')
print(f'P-value: {p_value}')

# Interpret the results
alpha = 0.01  # significance level
if p_value < alpha:
    print("The difference between the two groups is statistically significant.")
else:
    print("There is no statistically significant difference between the two groups.")

print(f"\nThe mean score for girls in regular class with aid {regular_with_aid_class_girl_score.mean()} and for boys in regular class with aid is
{regular_with_aid_class_boy_score.mean()}")
```

✓ 0.0s Python

```
T-statistic: 3.3250605820745864
P-value: 0.0008998637697378911
The difference between the two groups is statistically significant.

The mean score for girls in regular class with aid 461.96632653061226 and for boys in regular class with aid is 456.6753623188406
```

IN INDIA

- CLASS PERFORMANCE IN SCIENCES BEGINS TO DETERIORATE AFTER THE CLASS SIZE OF 41.
- THIS NUMBER IS AS HIGH AS 51 IN NON-SCIENCE CLASSES.
- US$ 3.6 BILLION INCURRED BY INDIA (2017-18) IN REDUCING PTR.
- REDUCING CLASS SIZE TO 30 OR BELOW IN SECONDARY EDUCATION MAY LOWER LEARNING AND INCREASE COSTS.
- PROPOSED INCREASING THE PTR TO 40 PUPILS PER TEACHER IN BOTH ELEMENTARY AND SECONDARY SCHOOLS, ESTIMATING A POTENTIAL ANNUAL SAVING OF USD 19.4 BILLION IN TEACHER SALARY EXPENSES WITHOUT COMPROMISING LEARNING OUTCOMES.

Home | rise programme. (n.d.). https://riseprogramme.org/sites/default/files/2021-01/RISE_WP-0059_Datta_Kingdon.pdf

THANK YOU