STATISTICAL EXAMINATION OF FACTORS AFFECTING STUDENT PERFORMANCE IN EXAM

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Outline

- Background
- Data Overview
- Descriptive Statistics
- Normality Test
- Hypothesis Test
- Post Hoc Test
- Conclusion

Background

Student exam performance may differ based on factors such as gender, parental education, test preparation, or lunch programs. This study applies statistical tests to explore whether these **factors** are **associated** with differences in math, reading, and writing exam scores. The goal is to identify statistical relationships rather than determine causal effects. To do so, we first test for **normality** to determine the appropriate statistical approach. Depending on the distribution, we apply either **parametric or non-parametric tests,** using **one-tailed** or **two-tailed** analyses based on the research questions. When significant differences are found, **post-hoc** tests will be provided to gain further insights

01 Assessing Data Normality

Before hypothesis testing, we examine whether the data follows a normal distribution.

02 If normality is confirmed

Parametric Tests

✅ t-test → Comparing two groups (e.g., test prep vs. no test prep)

✅ ANOVA → Comparing multiple groups (e.g., different parental education levels)

✅ Post Hoc Test → Tukey's HSD → Identifies which specific groups differ

03 If not..

Non-Parametric Tests

✅ Mann-Whitney U Test → Alternative to t-test for two groups

✅ Kruskal-Wallis Test → Alternative to ANOVA for multiple groups

✅ Post Hoc Tests (if Kruskal-Wallis is significant)

✅ Dunn's Test → Pairwise comparisons with multiple testing correction

✅ Effect Size → Cliff's Delta (for Mann-Whitney U test)

Data Overview

Data Collection:
https://www.kaggle.com/datasets/spscientist/students-performance-in-exams?select=StudentsPerformance.csv

independent variables

	Column Name	Number of Unique	Unique Sample
0	gender	2	[female, male]
1	race/ethnicity	5	[group B, group C, group A, group D, group E]
2	parental level of education	6	[bachelor's degree, some college, master's deg...
3	lunch	2	[standard, free/reduced]
4	test preparation course	2	[none, completed]
5	math score	81	[72, 69, 90, 47, 76, 71, 88, 40, 64, 38, 58, 6...
6	reading score	72	[72, 90, 95, 57, 78, 83, 43, 64, 60, 54, 52, 8...
7	writing score	77	[74, 88, 93, 44, 75, 78, 92, 39, 67, 50, 52, 4...

dependent variables

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 8 columns):
 #   Column                       Non-Null Count  Dtype 
---  ------                       --------------  ----- 
 0   gender                       1000 non-null   object
 1   race/ethnicity               1000 non-null   object
 2   parental level of education  1000 non-null   object
 3   lunch                        1000 non-null   object
 4   test preparation course      1000 non-null   object
 5   math score                   1000 non-null   int64 
 6   reading score                1000 non-null   int64 
 7   writing score                1000 non-null   int64 
dtypes: int64(3), object(5)
memory usage: 62.6+ KB
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Research Questions

1 DEMOGRAPHIC FACTORS

- Is there significant difference in math, reading, and writing score based on gender?
- how does race/ethnicity influence academic performance accross math, reading, and writing scores?

2 PARENTAL EDUCATION

- Does parental level of education affect student performance in math, reading and writing?
- Are students whose parents have bachelor's degree or higher more likely to score higher compared to those with lower educational background?

3 SCHOOL RESOURCE

- does the type of lunch program impact academic performance?
- are student on the free/reduced lunch program scoring significantly lower than those with standard lunch?

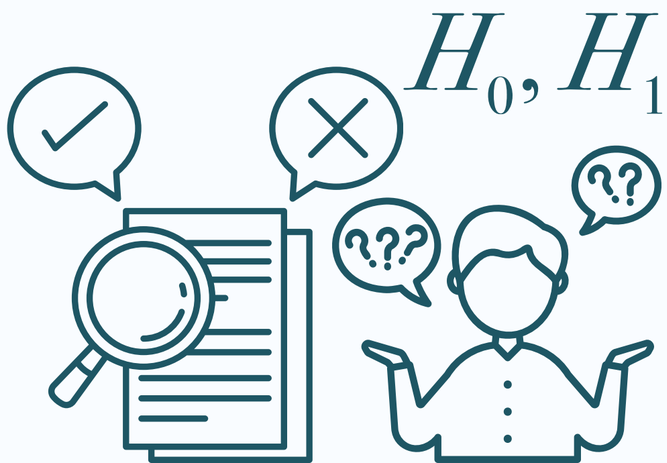
4 TEST PREPARATION

- do student who completed a test preparation course perform better in math, reading, writing compared to those who did not?
- is there a greater improvement in specific subject (math, reading, writing) after completing a test preparation course?

RQ 1 ON DEMOGRAPHIC FACTORS:

- Is there significant difference in math, reading, and writing score based on gender?
- how does race/ethnicity influence academic performance accross math, reading, and writing scores?

Hyphotesis on Demographic Factors

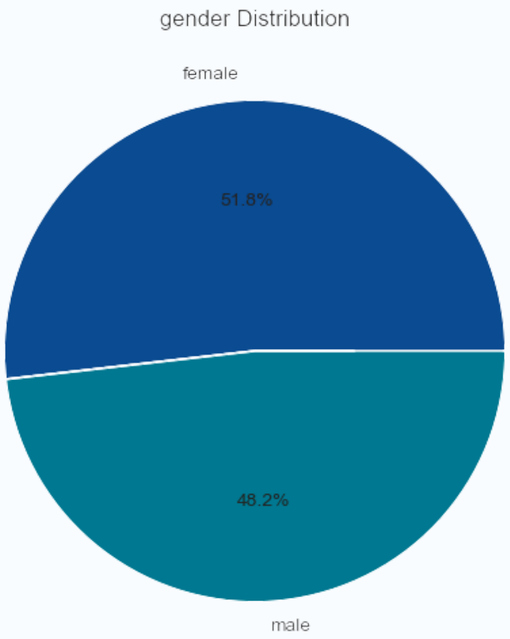


Gender

- H_{01}: There is no significant difference in math, reading, and writing scores between male and female students.
- H_{11}: There is a significant difference in math, reading, and writing scores between male and female students.

Race/Etnicity Group

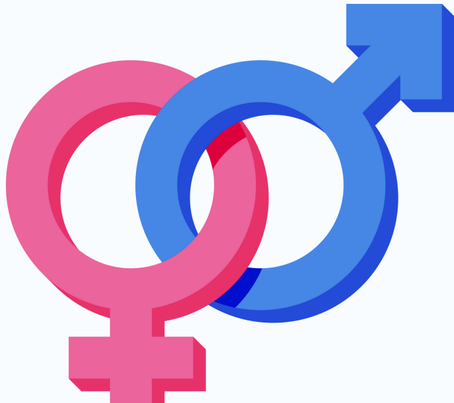
- H_{02}: There is no significant difference in academic performance across different race/ethnicity groups.
- H_{12}: There is a significant difference in academic performance across different race/ethnicity groups.



	gender	Count
0	female	518
1	male	482

Gender analysis

- There are two independent groups, hence if the data is not normally distributed, we may apply Mann-Whitney U Test
- We are going to use two tailed test since the research question type do not have directional hypothesis

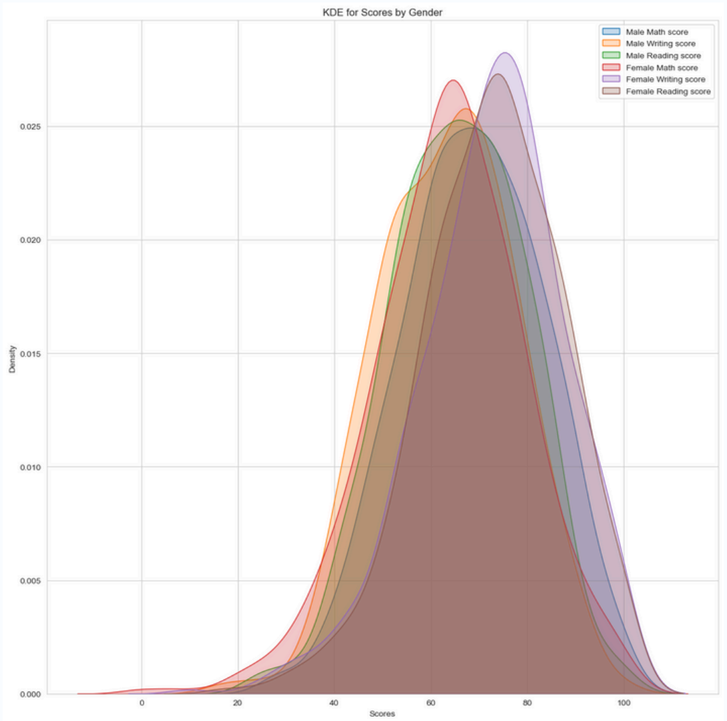


	gender	female	male
math score	mean	63.63	68.73
	median	65.00	69.00
	std	15.49	14.36
writing score	mean	72.47	63.31
	median	74.00	64.00
	std	14.84	14.11
reading score	mean	72.61	65.47
	median	73.00	66.00
	std	14.38	13.93

Descriptive Statistics

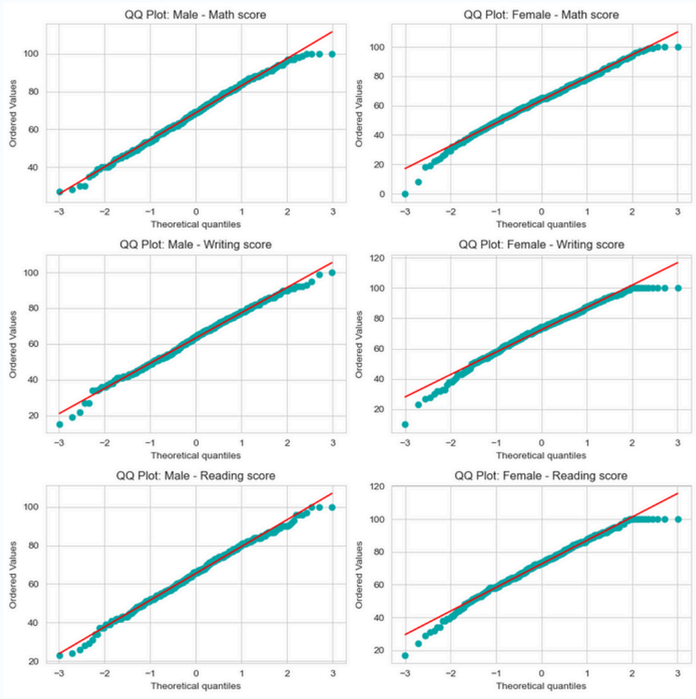
- male perform better in math
- female perform better in writing and reading

** mean and median are slightly different*



Bell-Curve Distribution

The distribution of academic scores between males and females appears similar, with slight differences in peak density. Distributions are seen left skewed



QQ Plot

Most values follow the red line (normal distribution), though slight deviations appear in the lower and upper tails. That being said, academic scores are relatively normal but have minor skewness or outliers.

	Gender	Score Type	Shapiro-Wilk p-value	Kolmogorov-Smirnov p-value	interpretation
0	female	math score	0.00351	0.27548	Not normal
1	male	math score	0.03802	0.45190	Not normal
2	female	reading score	0.00005	0.19947	Not normal
3	male	reading score	0.08965	0.25751	Normal
4	female	writing score	0.00000	0.03851	Not normal
5	male	writing score	0.10401	0.41626	Normal

We used **Shapiro-Wilk and Kolmogorov-Smirnov** to test whether data is normal. Turn out, most of them are not normal. Thus, use non parametrics

	Score Type	Mann-Whitney U Test Statistic	p-value
0	math score	147907.50000	0.00000
1	reading score	89168.00000	0.00000
2	writing score	79719.50000	0.00000

Since there are two independent groups, we used **Mann-Whitney U Test**. The p-value results are below 0.05. We can reject null hypothesis. That means distribution of scores are significantly differenct across all three subject

```
math score: Cliff's Delta = 0.185 (Small effect)
reading score: Cliff's Delta = -0.286 (Small effect)
writing score: Cliff's Delta = -0.361 (Medium effect)
```

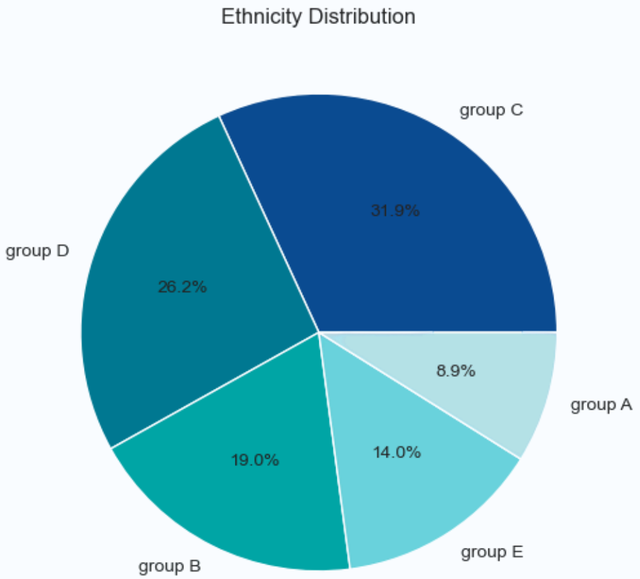
Deep dive, in post hoc **Cliff's Delta**, Male score, despite higher, but the effect is small. So is female, higher score in reading, but the effect is small. But in writing, the female outperforms males with medium effect/can be said significant.

Is there significant difference in math, reading, and writing score based on gender?

- ~~H_{01}: There is no significant difference in math, reading, and writing scores between male and female students.~~
- H_{11}: There is a significant difference in math, reading, and writing scores between male and female students. ✅

Therefore..

- The descriptive statistics results (male, better in math; female, better in reading and writing), indicating score differences between groups, were supported by the non-parametric Mann-Whitney U test and Cliff's Delta, which demonstrated statistical significance and effect size



Race/Ethnicity analysis

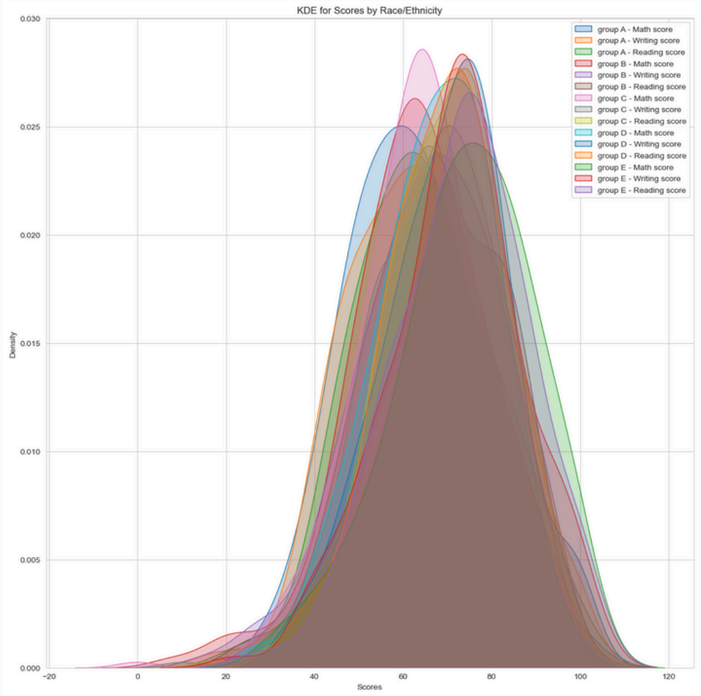
	Ethnicity	Count
0	group C	319
1	group D	262
2	group B	190
3	group E	140
4	group A	89

- There are more than two groups. that being said that Mann-Whitney U will no longer be used like previously applied step.
- If we find the data is normally distributed then we may apply ANOVA. But, if we find that normality test (Shapiro or Kolmogorov) p-value > 0.05, we are going to use Kruskal-Wallis

	race/ethnicity	group A	group B	group C	group D	group E
math score	mean	61.63	63.45	64.46	67.36	73.82
	median	61.00	63.00	65.00	69.00	74.50
	std	14.52	15.47	14.85	13.77	15.53
writing score	mean	62.67	65.60	67.83	70.15	71.41
	median	62.00	67.00	68.00	72.00	72.00
	std	15.47	15.63	14.98	14.37	15.11
reading score	mean	64.67	67.35	69.10	70.03	73.03
	median	64.00	67.00	71.00	71.00	74.00
	std	15.54	15.18	14.00	13.90	14.87

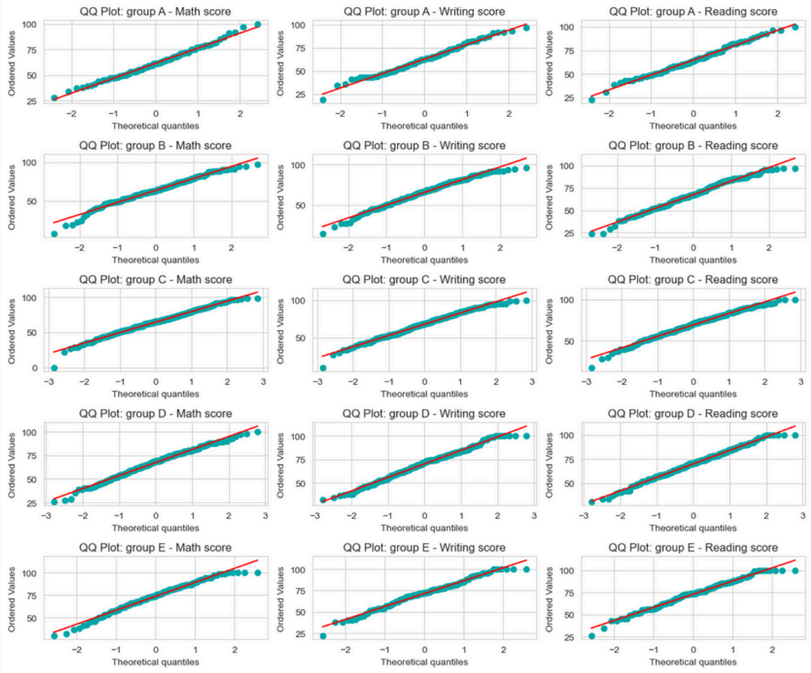
Descriptive Statistics

- in math, group E has greater mean and median score than the others but std also high
- in writing, group E is also has greater mean score, slightly above group D and has same median, but std is greater compared to D
- in reading, group E leads
- *Group E domminate all the subjects*



Bell-Curve Distribution

All ethnic groups have similar distribution shapes, with peak scores around 60–80



QQ Plot

The QQ plots show that all score distributions (Math, Reading, Writing) for different ethnic groups mostly follow a normal distribution, but some deviations occur at the tails

	Race/Ethnicity	Score Type	Shapiro-Wilk p-value	Kolmogorov-Smirnov p-value	Interpretation
0	group B	math score	0.01	0.55	Not normal
1	group C	math score	0.02	0.33	Not normal
2	group A	math score	0.85	0.99	Normal
3	group D	math score	0.06	0.37	Normal
4	group E	math score	0.02	0.87	Not normal
5	group B	reading score	0.05	0.53	Not normal
6	group C	reading score	0.01	0.08	Not normal
7	group A	reading score	0.80	0.98	Normal
8	group D	reading score	0.30	0.65	Normal
9	group E	reading score	0.08	0.35	Normal
10	group B	writing score	0.02	0.64	Not normal
11	group C	writing score	0.02	0.75	Not normal
12	group A	writing score	0.60	0.98	Normal
13	group D	writing score	0.05	0.23	Not normal
14	group E	writing score	0.07	0.39	Normal

Normality Test

Since the results are varied, our decision is not to use parametrics, rather non parametrics, and because of independent group is more than 2, we will apply Kruskall-Wellis Test

	Score Type	Kruskal-Wallis Statistic	p-value
0	math score	57.08	0.00
1	writing score	26.61	0.00
2	reading score	21.35	0.00

Kruskall-Wallis Result

Since all p-values are < 0.05, we reject the null hypothesis (H_{02}) and conclude that there is a significant difference in academic performance across different race/ethnicity groups for math, reading, and writing scores

as we know that Kruskal-Wallis only tells at least one group differs, and nothing to do with which group has significance difference, we are going to undertake post hoc test namely Dunn's Test.

```
Dunn's Test for math score:

          group A  group B  group C  group D  group E
group A      1.00     1.00     0.67     0.01     0.00
group B      1.00     1.00     1.00     0.07     0.00
group C      0.67     1.00     1.00     0.13     0.00
group D      0.01     0.07     0.13     1.00     0.00
group E      0.00     0.00     0.00     0.00     1.00

Dunn's Test for reading score:

          group A  group B  group C  group D  group E
group A      1.00     1.00     0.08     0.03     0.00
group B      1.00     1.00     1.00     0.97     0.01
group C      0.08     1.00     1.00     1.00     0.11
group D      0.03     0.97     1.00     1.00     0.40
group E      0.00     0.01     0.11     0.40     1.00

Dunn's Test for writing score:

          group A  group B  group C  group D  group E
group A      1.00     0.82     0.04     0.00     0.00
group B      0.82     1.00     1.00     0.05     0.01
group C      0.04     1.00     1.00     0.77     0.20
group D      0.00     0.05     0.77     1.00     1.00
group E      0.00     0.01     0.20     1.00     1.00
```

Dunn Result

- Group E consistently shows the most significant differences across all subjects
- Math Score → Group E is significantly different from all others; Group D differs from A & B.
- Reading Score → Group E stands out; Group D is similar to B & C.
- Writing Score → Groups A & E show the biggest differences; B & C are nearly identical

how does race/ethnicity influence academic performance accross math, reading, and writing scores?

- ~~H_{02}: There is no significant difference in academic performance across different race/ethnicity groups.~~
- H_{12}: There is a significant difference in academic performance across different race/ethnicity groups. ✅

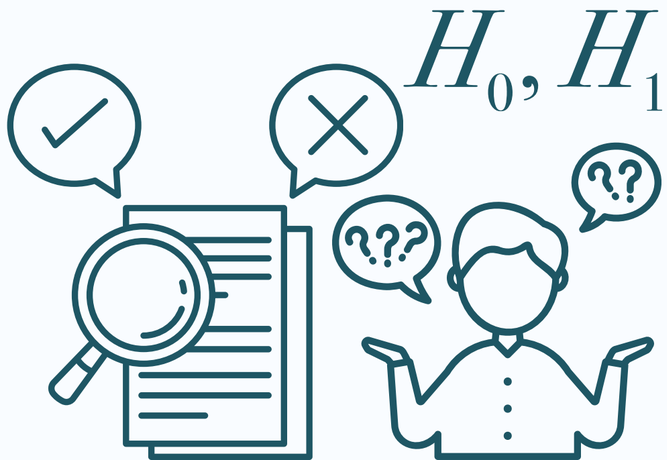
Therefore..

- H_{02} is rejected → Race/ethnicity has a statistically significant impact on academic performance.
- Students from group E perform better across all subjects, while others (e.g., Group A) tend to have lower scores.

RQ 2 ON PARENTAL EDUCATION FACTORS:

- Does parental level of education affect student performance in math, reading and writing?
- Are student whose parents have bachelors degree or higher more likely to score higher compared to those with lower educational background?

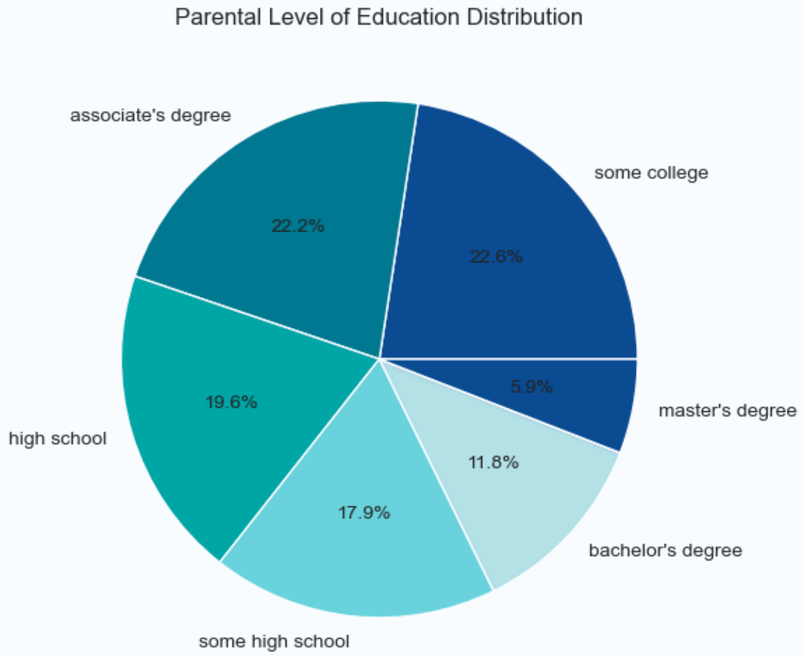
Hyphotesis on Parental Education



Parental Education

- H_{03}: There is no significant difference in math, reading, and writing scores based on parental level of education.
- H_{13}: There is a significant difference in math, reading, and writing scores based on parental level of education.

- H_{04}: Students whose parents have a bachelor’s degree or higher do not perform significantly better than those whose parents have lower education levels.
- H_{14}: Students whose parents have a bachelor’s degree or higher perform significantly better than those whose parents have lower education levels.



	Parental Level of Education	Count
0	some college	226
1	associate's degree	222
2	high school	196
3	some high school	179
4	bachelor's degree	118
5	master's degree	59

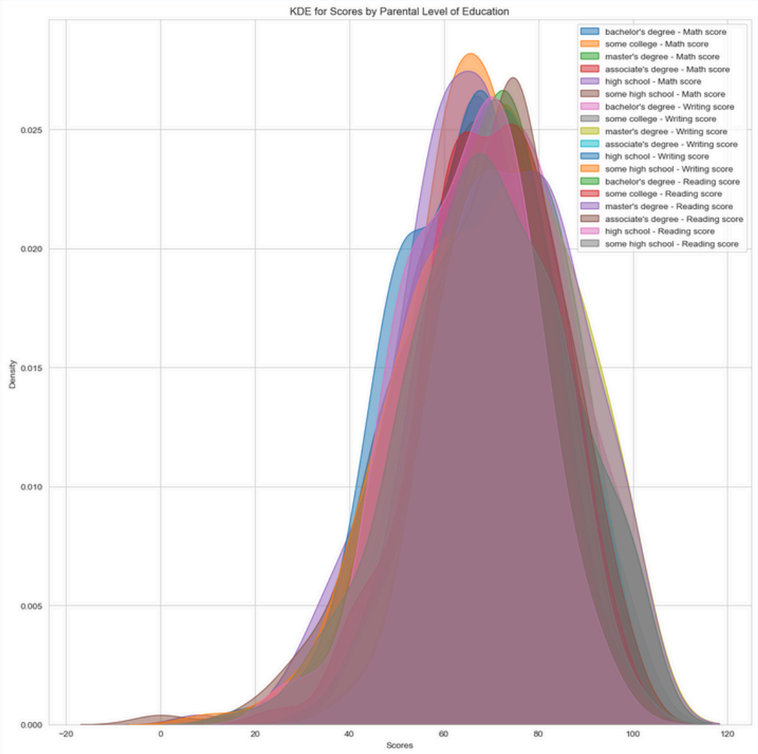
Parental Level of Education analysis

- There are six independent groups to be analyzed
- some college, which refer to those parent who attended college and completed some courses but did not earn a degree and associte degree are two most dominant parental level of education
- bachelor’s and master's are minority groups

	parental level of education	associate's degree	bachelor's degree	high school	master's degree	some college	some high school
math score	mean	67.88	69.39	62.14	69.75	67.13	63.50
	median	67.00	68.00	63.00	73.00	67.50	65.00
	std	15.11	14.94	14.54	15.15	14.31	15.93
writing score	mean	69.90	73.38	62.45	75.68	68.84	64.89
	median	70.50	74.00	64.00	75.00	70.00	66.00
	std	14.31	14.73	14.09	13.73	15.01	15.74
reading score	mean	70.93	73.00	64.70	75.37	69.46	66.94
	median	72.50	73.00	66.00	76.00	70.50	67.00
	std	13.87	14.29	14.13	13.78	14.06	15.48

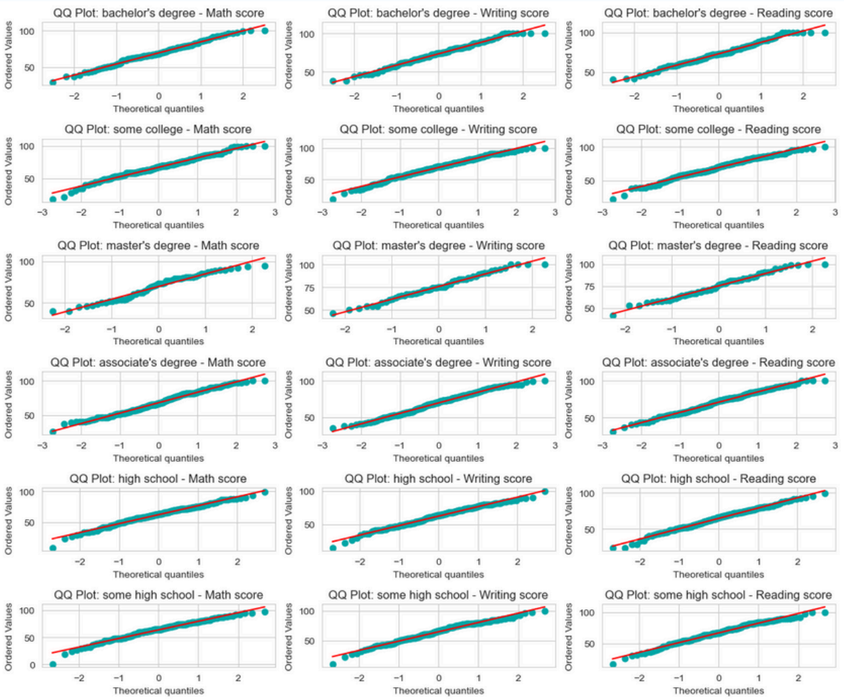
Descriptive Statistics

- Higher Education, Higher Scores: Generally, as parental education level increases, median scores in math, writing, and reading tend to rise. Master's degree holders consistently show the highest median scores across all three subjects.
- Math is the Weakest Area: Math scores are consistently lower than writing and reading scores across all parental education levels



Bell-Curve Distribution

it seems there are skewed in these parental level of education table distribution



QQ Plot

There are visible deviations from the red (normal) line in several plots, especially at the tails of the distributions (the ends of the plots). This indicates that the data does not perfectly follow a normal distribution.

	Parental Education	Score Type	Shapiro-Wilk p-value	Kolmogorov-Smirnov p-value	Interpretation
0	bachelor's degree	math score	0.60	0.79	Normal
1	some college	math score	0.10	0.32	Normal
2	master's degree	math score	0.03	0.29	Not normal
3	associate's degree	math score	0.04	0.41	Not normal
4	high school	math score	0.07	0.35	Normal
5	some high school	math score	0.01	0.17	Not normal
6	bachelor's degree	reading score	0.12	0.71	Normal
7	some college	reading score	0.04	0.57	Not normal
8	master's degree	reading score	0.39	0.90	Normal
9	associate's degree	reading score	0.15	0.40	Normal
10	high school	reading score	0.21	0.59	Normal
11	some high school	reading score	0.06	0.79	Normal
12	bachelor's degree	writing score	0.16	0.95	Normal
13	some college	writing score	0.02	0.53	Not normal
14	master's degree	writing score	0.41	0.83	Normal
15	associate's degree	writing score	0.06	0.52	Normal
16	high school	writing score	0.13	0.38	Normal
17	some high school	writing score	0.02	0.19	Not normal

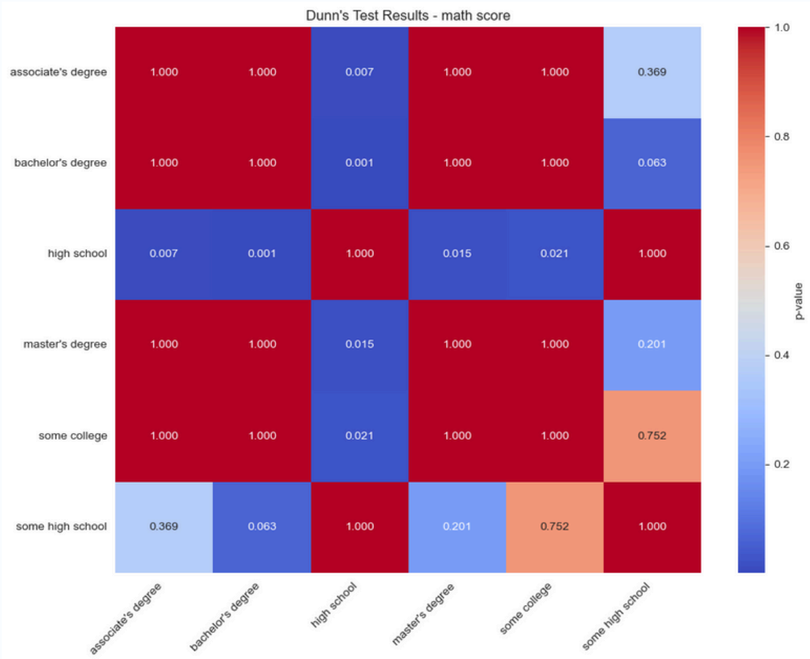
Normality Test

- The normality table above is seen to be dominated by normal distribution. However since another parental education is not normal, rather than using transformation log, we are going to decide non parametrics test

	Score Type	Kruskal-Wallis Statistic	p-value
0	math score	26.51	0.00
1	reading score	38.66	0.00
2	writing score	62.33	0.00

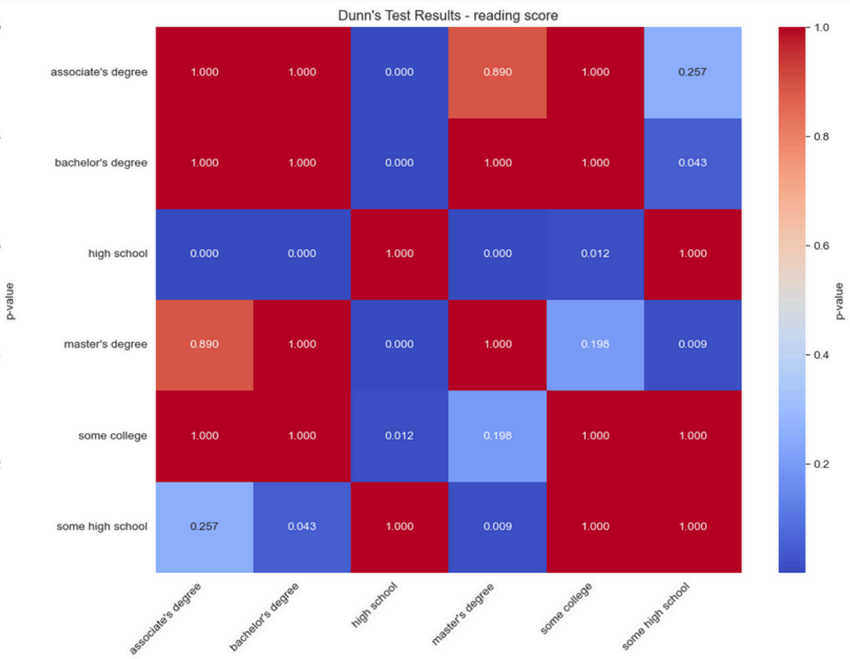
Kruskal Wallis Statistic

Since p-values for all three scores (math, reading, writing) are < 0.05, we reject H_{03}.
We can say that there is a significant difference in academic performance based on parental education level



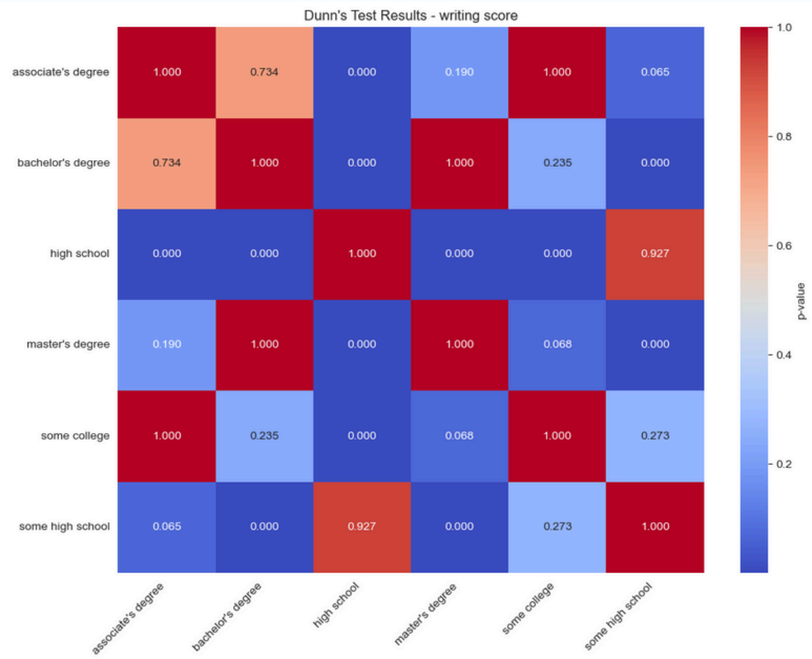
Dunn Math Score

- The significant differences (low p-value, blue color) between 'master's degree' and 'bachelor's degree' are only visible when compared to 'high school' and 'some high school'



Dunn’ Reading Score

- Bachelor's Degree: Reading scores differ significantly only when compared to "high school" and "some high school" groups. No significant difference is observed with "associate's degree" or "some college."
- Master's Degree: Shows no significant difference when compared to "associate's degree" or "bachelor's degree." However, it shows significant differences compared to all other lower education level groups.



Dunn’ Writing Score

- both "bachelor's degree" and "master's degree" groups show significant differences (low p-values, blue color) when compared to all lower parental education level groups ("associate's degree," "high school," "some college," and "some high school").

	Score Type	Cliff's Delta	Effect Size
0	math score	0.15	Small effect
1	reading score	0.20	Small effect
2	writing score	0.27	Small effect

When we grouped bachelor's and master's to be analyzed along with the rests

- applied mann whitney U, where the results: p-values < alpha
- and utilized the clift's delta, despite significance, turn out the effect is all small

Does parental level of education affect student performance in math, reading and writing?

- ~~H_{03}: There is no significant difference in math, reading, and writing scores based on parental level of education.~~
- H_{13}: There is a significant difference in math, reading, and writing scores based on parental level of education.

Therefore..

- The descriptive statistics results demonstrating that the more higher the parental level of education, were supported by the non-parametric Kruskall Wallist test that each of parental level education has significant difference in scores

are student whose parents have bachelors degree or higher more likely to score higher compared to those with lower educational background?

- ~~H_{04}: Students whose parents have a bachelor's degree or higher do not perform significantly better than those whose parents have lower education levels.~~
- - H_{14}: Students whose parents have a bachelor's degree or higher perform significantly better than those whose parents have lower education levels.

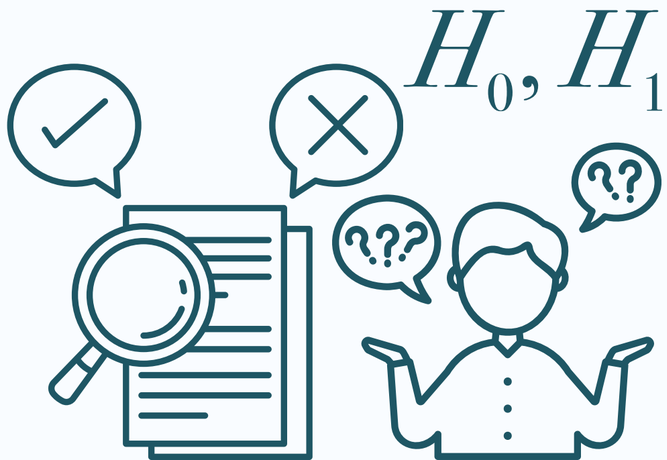
Therefore..

- Students whose parents have a Bachelor's degree or higher tend to have higher scores compared to those whose parents have lower education levels, which is particularly evident in writing scores. Support for this hypothesis (H_{14}) varies across subjects and depends on which lower education level groups are being compared. The most consistent and significant differences are observed when higher education groups are compared to basic education groups (High School and Some High School)

RQ 3 ON SCHOOL RESOURCE

- Is there a significant difference in academic performance between students in different lunch programs?
- Are student on the free/reduced lunch program scoring significantly lower than those with standard lunch?

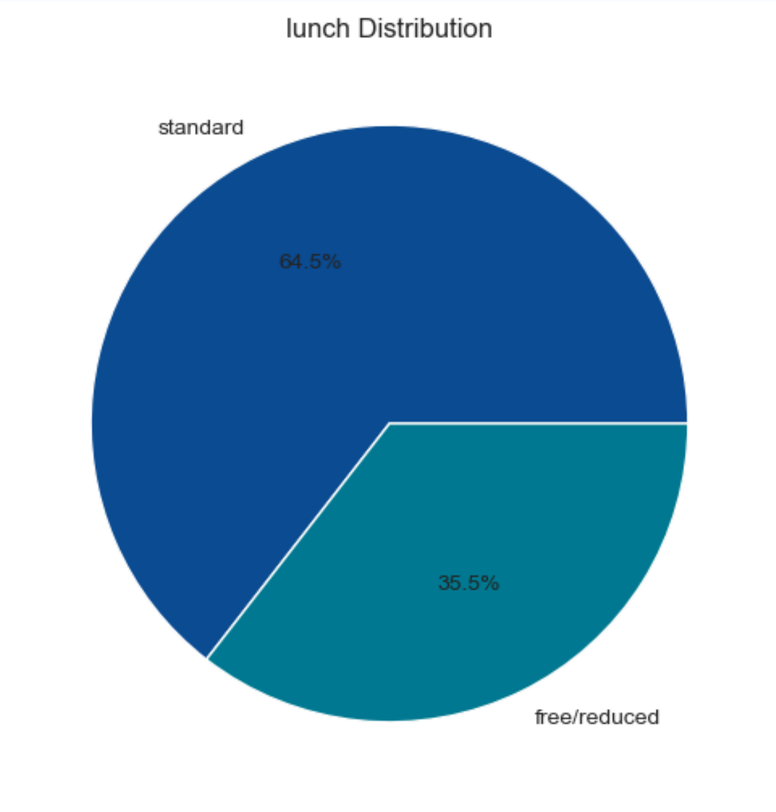
Hyphotesis on Lunch



Lunch Program

- H_{05}: There is no significant difference in academic performance between students receiving standard lunch and those on the free/reduced lunch program.
- H_{15}: There is a significant difference in academic performance between students receiving standard lunch and those on the free/reduced lunch program.

- H_{06}: Students on the free/reduced lunch program do not score significantly lower than those on the standard lunch program.
- H_{16}: Students on the free/reduced lunch program score significantly lower than those on the standard lunch program.



Lunch analysis

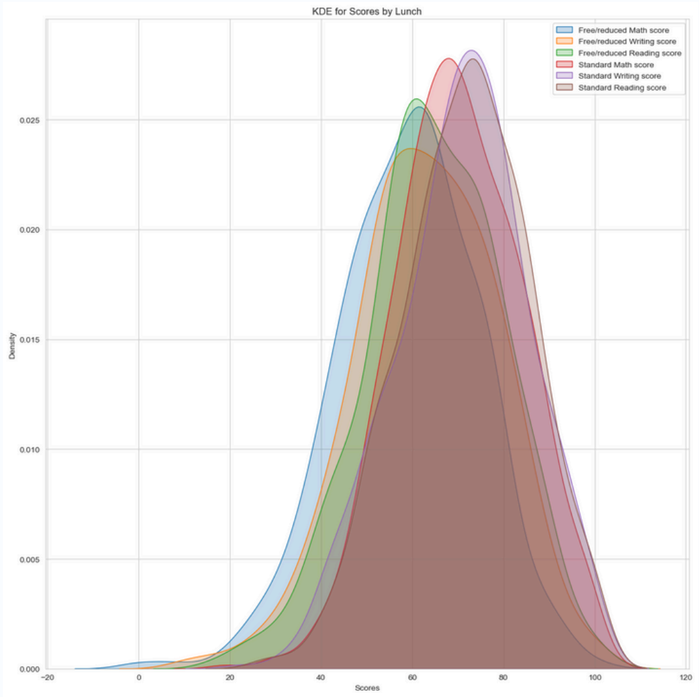
- There are two groups in this analysis where majority of student are in standard lunch with 64,5%.When the normality test says data is normal we are going to use t-test. However, when it is not, Man Whitney U test.
- Because of the research questions, we are going to apply both one tailed and two tailed

	lunch	Count
0	standard	645
1	free/reduced	355

	lunch	free/reduced	standard
math score	mean	58.92	70.03
	median	60.00	69.00
	std	15.16	13.65
writing score	mean	63.02	70.82
	median	64.00	72.00
	std	15.43	14.34
reading score	mean	64.65	71.65
	median	65.00	72.00
	std	14.90	13.83

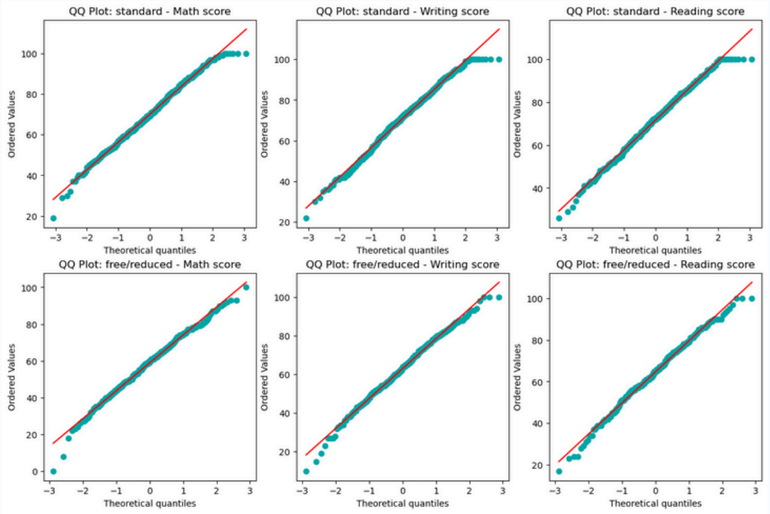
Descriptive Statistics

- standard type of lunch is consistently higher in all exam score
- mean and median are so close in range



Bell-Curve Distribution

looks normally distributed with some skewed



QQ Plot

tails are out from red lines

	Lunch Type	Score Type	Shapiro-Wilk p-value	Kolmogorov-Smirnov p-value	interpretation
0	standard	math score	0.02	0.50	Not normal
1	free/reduced	math score	0.07	0.55	Normal
2	standard	reading score	0.00	0.20	Not normal
3	free/reduced	reading score	0.13	0.48	Normal
4	standard	writing score	0.00	0.10	Not normal
5	free/reduced	writing score	0.15	0.76	Normal

Normality Test

- Some are normal and the other are not. We are going to use non parametric, Mann Whitney U test to see whether there is a significant difference

	Score Type	Mann Whitney U Statistic	p-value
0	math score	161077.00	0.00
1	reading score	144848.00	0.00
2	writing score	147389.00	0.00

Mann Whitney U Test

- P-Value is below alpha, 0.05. That being said, there is a significant different between lunch type
- this is a two tailed to answer the first question, so we can reject H_{06}

```
math score: Cliff's Delta = 0.407 (Medium effect)
reading score: Cliff's Delta = 0.265 (Small effect)
writing score: Cliff's Delta = 0.287 (Small effect)
```

Cliff's Delta

- Students with standard lunch tend to have higher math scores compared to those receiving free/reduced lunch. (medium/moderate)
- in reading and writing standard lunch is slightly better

Does the type of lunch program impact academic performance?

- ~~H_{06}: There is no significant difference in academic performance between students receiving standard lunch and those on the free/reduced lunch program.~~
- H_{16}: There is a significant difference in academic performance between students receiving standard lunch and those on the free/reduced lunch program

Are students on the free/reduced lunch program scoring significantly lower than those with standard lunch?

```
math score:
  Mann-Whitney U: Statistic = 161077.000, p-value = 0.000
  Cliff's Delta: Delta = -0.407 (Medium effect)
  Conclusion: H07 rejected, H17 accepted. Students with free/reduced lunch scored significantly lower.

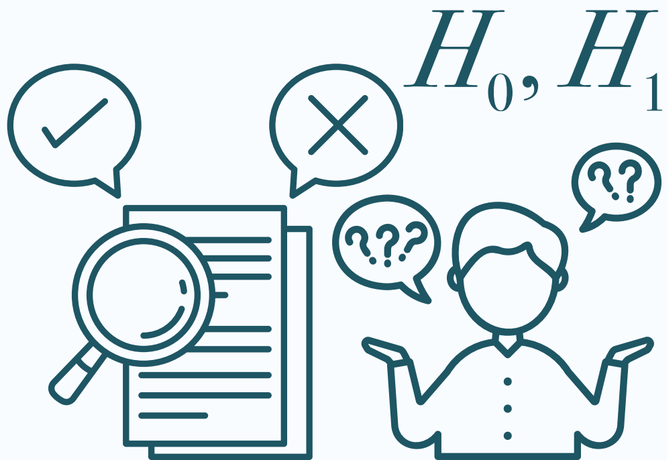
reading score:
  Mann-Whitney U: Statistic = 144848.000, p-value = 0.000
  Cliff's Delta: Delta = -0.265 (Small effect)
  Conclusion: H07 rejected, H17 accepted. Students with free/reduced lunch scored significantly lower.

writing score:
  Mann-Whitney U: Statistic = 147389.000, p-value = 0.000
  Cliff's Delta: Delta = -0.287 (Small effect)
  Conclusion: H07 rejected, H17 accepted. Students with free/reduced lunch scored significantly lower.
```

RQ 4 ON TEST PREPARATION COURSE

- do student who completed a test preparation course perform better in math, reading, writing compared to those who did not?

Hyphotesis on Test Preparation

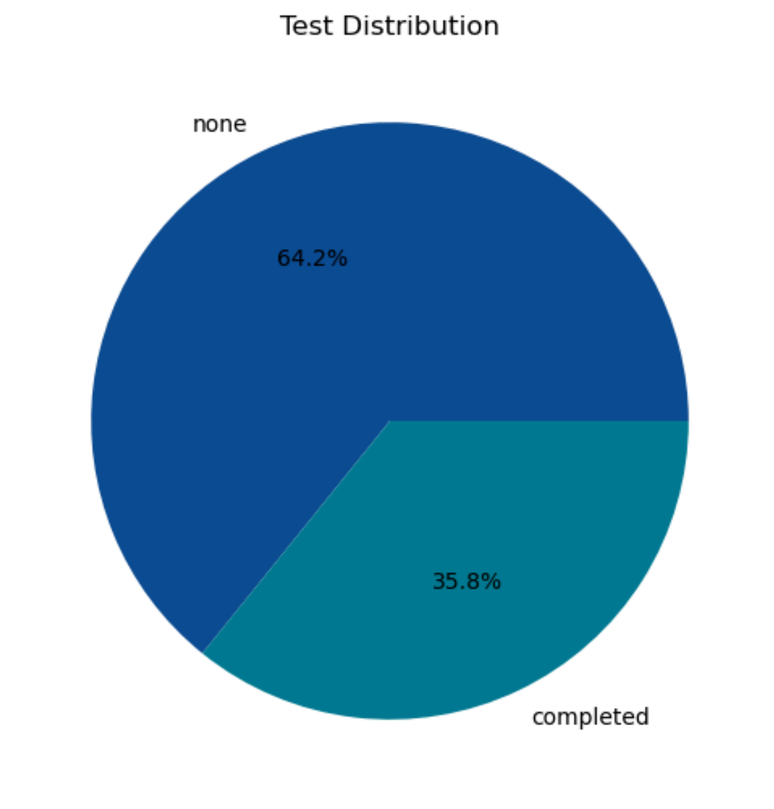


Test Preparation

Do student who completed a test preparation course perform better in math, reading, writing compared to those who did not?

- H_{01}: There is no significant difference in math, reading, and writing scores between students who completed a test preparation course and those who did not.
- H_{11}: Students who completed a test preparation course score significantly higher in math, reading, and writing than those who did not.

	Test Preparation	Count
0	none	642
1	completed	358



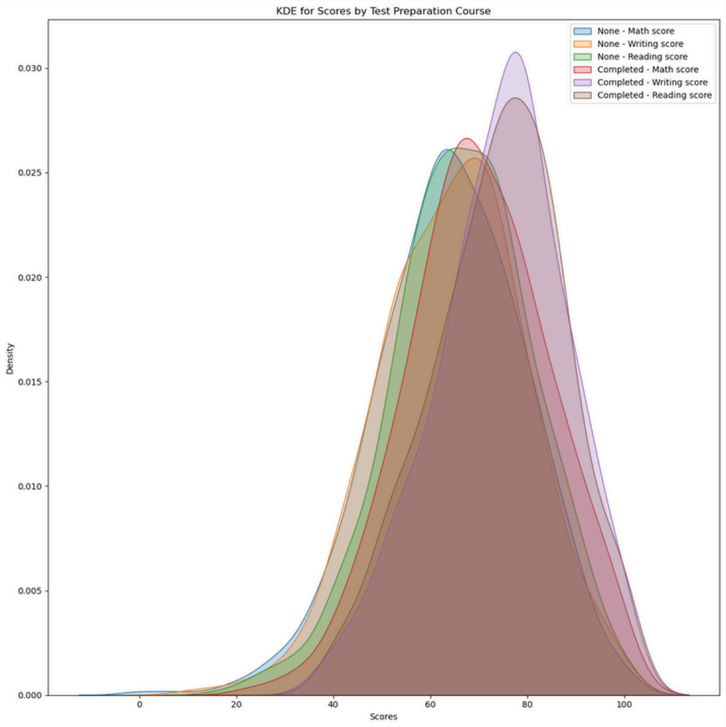
Test analysis

- There are two groups in this test analysis where majority of student do not take tes preparation with 64%. When the normality test says data is normal we are going to use t-test. However, when it is not, Man Whitney U test with one tailed

	test preparation course	completed	none
math score	mean	69.70	64.08
	median	69.00	64.00
	std	14.44	15.19
writing score	mean	74.42	64.50
	median	76.00	65.00
	std	13.38	15.00
reading score	mean	73.89	66.53
	median	75.00	67.00
	std	13.64	14.46

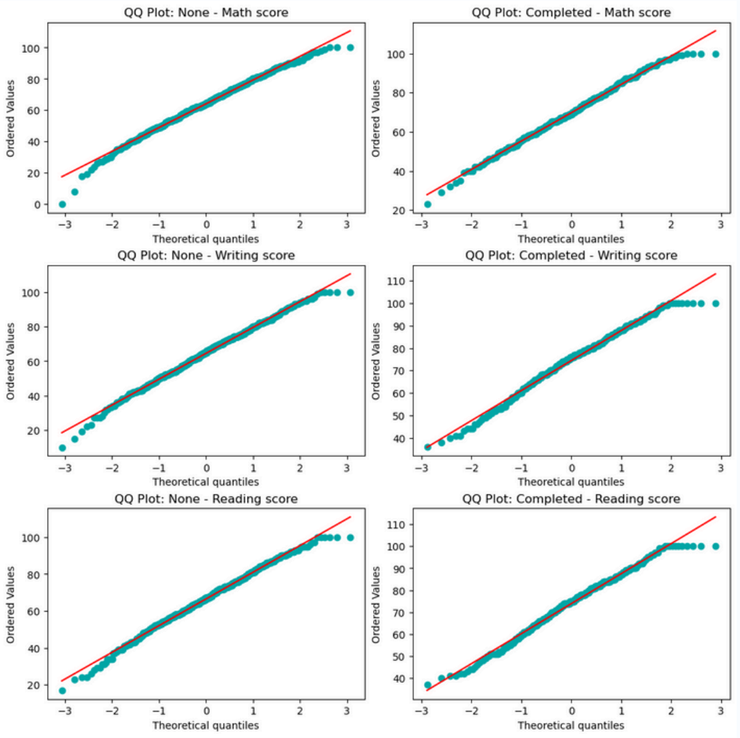
Descriptive Statistics

- those who completed test preparation before have greater score in all subjects



bell-shaped distribution

- it looks normally distibuted, but alse negatively skewed



QQ-Plot

- like previously observed, some deviation are in the tails, outlier

	test preparation course	Score Type	Shapiro-Wilk p-value	Kolmogorov-Smirnov p-value	Interpretation
0	none	math score	0.00	0.35	Not normal
1	completed	math score	0.14	0.92	Normal
2	none	reading score	0.02	0.30	Not normal
3	completed	reading score	0.00	0.10	Not normal
4	none	writing score	0.04	0.35	Not normal
5	completed	writing score	0.00	0.17	Not normal

Normality Test

- only one is normally distributed, the rests are not

	Score Type	Test	Statistic	p-value	Cliff's Delta	Effect Size
0	math score	Mann-Whitney U (one-tailed)	138412.00	0.00	0.20	Small effect
1	reading score	Mann-Whitney U (one-tailed)	148497.00	0.00	0.29	Small effect
2	writing score	Mann-Whitney U (one-tailed)	158809.00	0.00	0.38	Medium effect

Mann Whitney U Test and Cliff Delta

- From the Mann-Whitney U test results (since the data is not normally distributed), we see that all p-values = 0.00, which means the results are highly significant ($p < 0.05$).
- Thus, We reject H_{01} and accept H_{11} → Students who completed the test preparation course scored significantly higher in math, reading, and writing compared to those who did not take the course.
- However only writing score that effect size is medium while the other is small

Reach me out!

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Memoirs compiled by William Burch