Hypothesis Testing on Students before and after tutorials

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Problem Statement

It has been claimed that tutorials are helping student to improve their understanding in their study. Investigators want to know if this statement is true by performing Paired-samples t-test.

The hypothesis test is set as follows:

H0:μΔ=0

HA:μΔ≠0

Load Packages

```
library(readxl)
library(magrittr)
library(dplyr)
library(lattice)
library(ggplot2)
library(car)
```

Data

```
# Read the file
tutorial <- read.csv('data4b-1.csv')

# Rename the typo columns
names(tutorial)[names(tutorial) == "Score.without.after.tutorial"] <- "After"
names(tutorial)[names(tutorial) == "Score.without.before.tutorial"] <- "Before"

colnames(tutorial)
```

```
## [1] "Gender"     "IQ"         "Profession" "Advice"     "School"
## [6] "After"      "Before"
```

Descriptive Statistics

```
# After tutorial
tutorial %>% summarise (
  Min = min(After, na.rm=TRUE),
  Q1 = quantile(After, probs=.25, na.rm=TRUE),
  Median = median(After, na.rm=TRUE),
  Q3 = quantile(After, probs=.75, na.rm=TRUE),
  Max = max(After, na.rm=TRUE),
  Mean = mean(After, na.rm=TRUE),
  SD = sd(After, na.rm=TRUE),
  n = n(),
  Missing = sum(is.na(After))
)
```

Min <int>	Q1 <dbl>	Median <dbl>	Q3 <dbl>	Max <int>	Mean <dbl>	SD <dbl>	n <int>	Missing <int>
33	37	41	44	55	41.17132	4.952305	1290	0

1 row

```
# Before tutorial
tutorial %>% summarise (
  Min = min(Before, na.rm=TRUE),
  Q1 = quantile(Before, probs=.25, na.rm=TRUE),
  Median = median(Before, na.rm=TRUE),
  Q3 = quantile(Before, probs=.75, na.rm=TRUE),
  Max = max(Before, na.rm=TRUE),
  Mean = mean(Before, na.rm=TRUE),
  SD = sd(Before, na.rm=TRUE),
  n = n(),
  Missing = sum(is.na(Before))
)
```

Min <int>	Q1 <dbl>	Median <dbl>	Q3 <dbl>	Max <int>	Mean <dbl>	SD <dbl>	n <int>	Missing <int>
13	27	37	44	55	35.82093	10.53833	1290	0

1 row

```
# Add a new column for difference between after and before
tutorial <- tutorial %>% mutate(d=After - Before)

# Calculate the descriptive statistics
tutorial %>% summarise (
  Min = min(d, na.rm=TRUE),
  Q1 = quantile(d, probs=.25, na.rm=TRUE),
  Median = median(d, na.rm=TRUE),
  Q3 = quantile(d, probs=.75, na.rm=TRUE),
  Max = max(d, na.rm=TRUE),
  Mean = mean(d, na.rm=TRUE),
  SD = sd(d, na.rm=TRUE),
  n = n(),
  Missing = sum(is.na(d))
)
```

Min <int>	Q1 <dbl>	Median <dbl>	Q3 <dbl>	Max <int>	Mean <dbl>	SD <dbl>	n <int>	Missing <int>
-14	0	0	14	31	5.350388	10.03793	1290	0

1 row

Paired Samples t-test

We will perform Paired-sample t-test (one-sample t-test for the difference between Before and After tutorial) to investigate whether there is any significant different.

```
# Paired sample t-test check/one-sample t-test of the differences
t.test(tutorial$d, mu = 0, alternative = "two.sided")
```

```
##
##  One Sample t-test
##
## data:  tutorial$d
## t = 19.144, df = 1289, p-value < 2.2e-16
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  4.802104 5.898671
## sample estimates:
## mean of x
##  5.350388
```

```
# Assuming a two-tailed test with α = 0.05, the critical value is calculate as:
qt(p=0.025, df=1290-1)
```

```
## [1] -1.961806
```

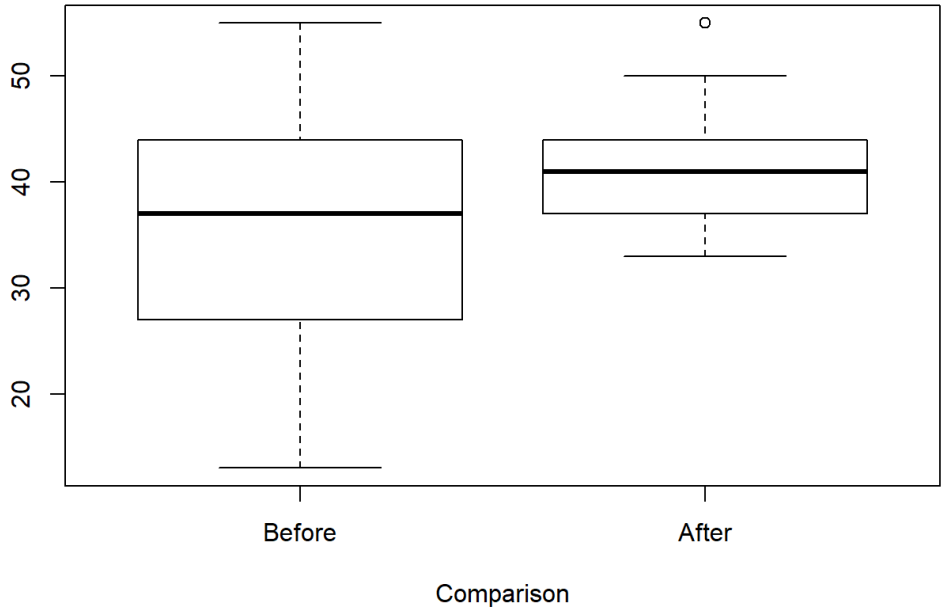
```
# The two-tailed p-value:
2*pt(q=19.144, df =1290-1)
```

```
## [1] 2
```

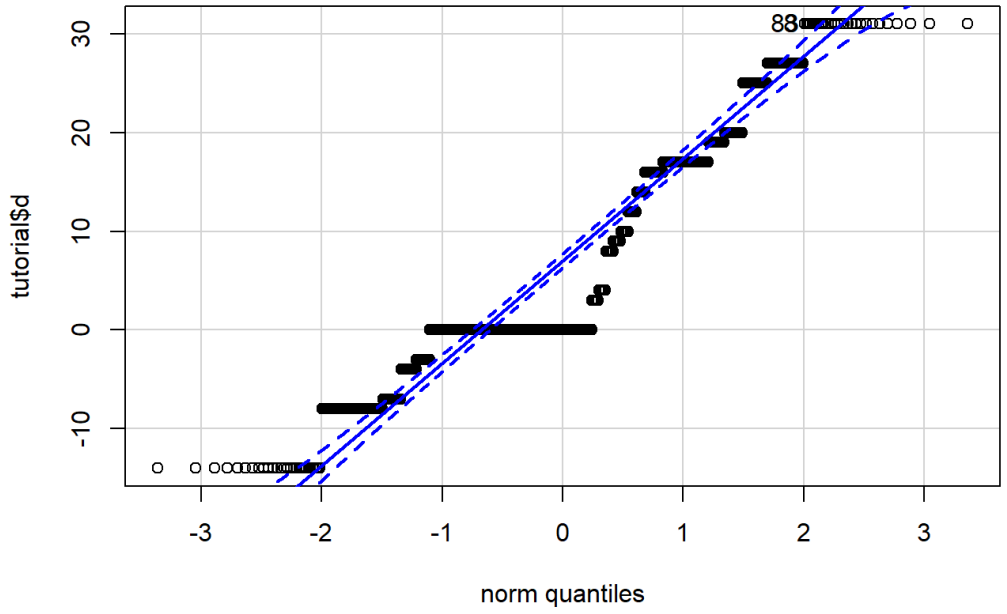
Visualisation

Upon performing boxplot, there seems to be an outlier in after tutorial data. However, the outlier is real and therefore is needed. Several visualizations such as QQ plot, Matplot, and Granova were also performed to check the improvement of the score.

```
# Boxplot
boxplot(tutorial$Before, tutorial$After, xlab="Comparison")
axis(1, at=1:2,labels=c("Before", "After"))
```

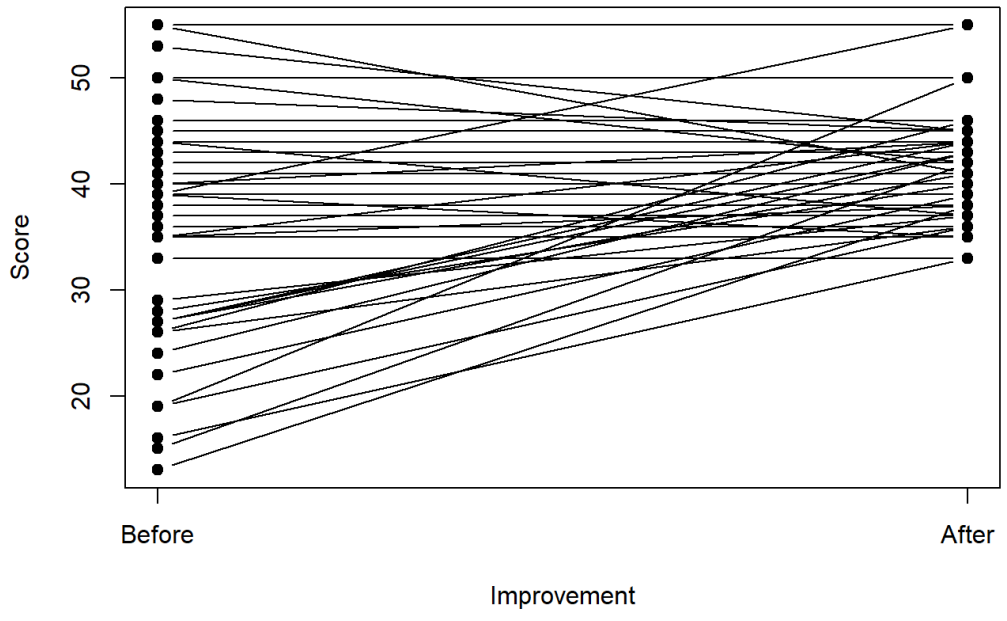



```
# QQ Plot
qqPlot(tutorial$d, dist="norm")
```




```
## [1]  8 83
```

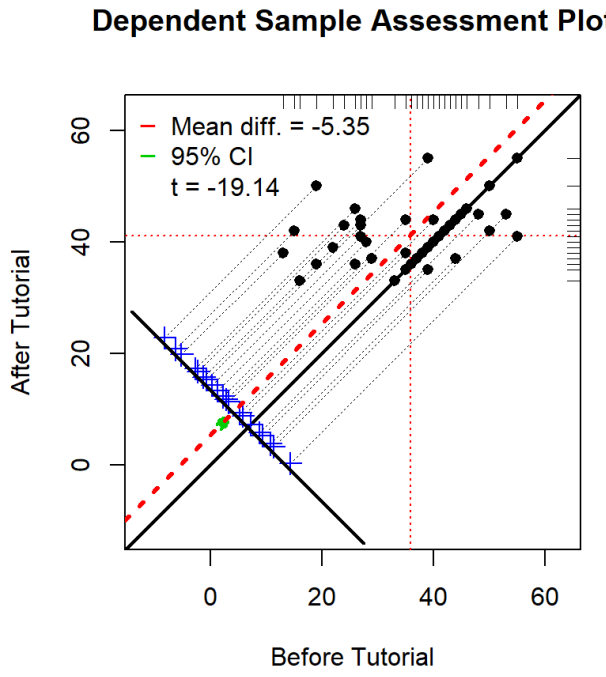
```
# Matplot
matplot(t(data.frame(tutorial$Before, tutorial$After)),
        type="b",
        pch=19,
        col=1,
        lty=1,
        xlab="Improvement",
        ylab="Score",
        xaxt="n"
        )
axis(1, at=1:2, labels=c("Before", "After"))
```




```
library(granova)
```

```
## Warning: package 'granova' was built under R version 3.6.3
```

```
granova.ds(data.frame(tutorial$Before, tutorial$After),
           xlab="Before Tutorial",
           ylab="After Tutorial")
```




```
##             Summary Stats
## n                1290.000
## mean(x)            35.821
## mean(y)            41.171
## mean(D=x-y)        -5.350
## SD(D)              10.038
## ES(D)              -0.533
## r(x,y)              0.334
## r(x+y,d)            0.660
## LL 95%CI           -5.899
## UL 95%CI           -4.802
## t(D-bar)          -19.144
## df.t             1289.000
## pval.t              0.000
```


Conclusion

A paired sample t-test was used to test for a significant mean difference between the scores of students before and after tutorial. The mean difference following tutorial was found to be 5.350, SD = 10.038. Visual inspection of the Q-Q plot measuring the difference suggested that the data were approximately normally distributed. The paired-sample t-test found a statistically significant mean difference between scores before and after tutorial with t(df=1289) = 19.144, p < 0.001, 95% [4.80, 5.90]. The t critical value is ± 1.962.

Scores were found to be significantly improved after tutorial.