F22B GenomicsCURE Assessment

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Assessing student outcomes of the fall 2022-B pilot genomics CURE

The pre- and post-asssement

The fall 2022-B pilot CURE required students to complete a pre- and post-examination to evaluate course outcomes. The pre-assessment acted as a baseline of individual student knowledge, and was divided into three learning submodules or topic areas: - (1) Biology - (2) Coding - (3) Professional development (research)

An additional section for self-reported student comfort and skill levels was included and evaluated independently: - (4) Personal feelings

The Weekly Progress Report

Students submitted weekly progress reports in open-repsonse format, and their organic feedback on challenges and how they addressed them (coping strategies), were also evaluated independently.

Based on these datasets, the following questions were asked to evaluate the impact of an asynchrous online CURE on student ability to analyze and impact data: - (1) Q1: Can a remote CURE increase student ability to interpret and analyze data? (quantitative) - (2) Q2: How does a remote CURE affect student comfort levels in computational research? (quantitative) - (3) Q3: What self-reported coping strategies did students use to overcome asynchronous challenges? (qualitative)

Install and load packages

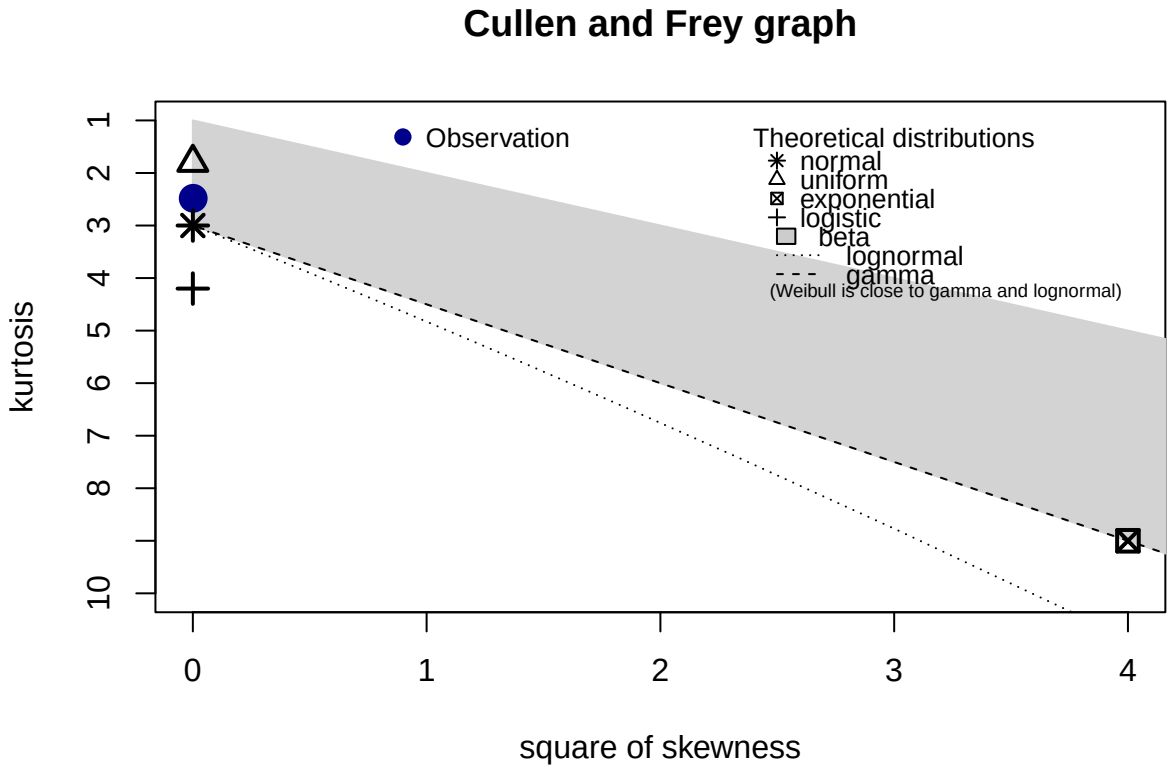
Input the data for the Fall 2022B pilot CURE

```
# Set your working directory to your path of choice
# setwd('C:/Users/splaisie/Dropbox
# (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/')

overall_scores <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22
View(overall_scores)

deltas_overall <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22
View(overall_scores)

# Reduce the number of decimal places as a global option
options(digits = 4)
```

```
# Input the results of both treatments
combined_scores <- data.frame(deltas_overall)
```

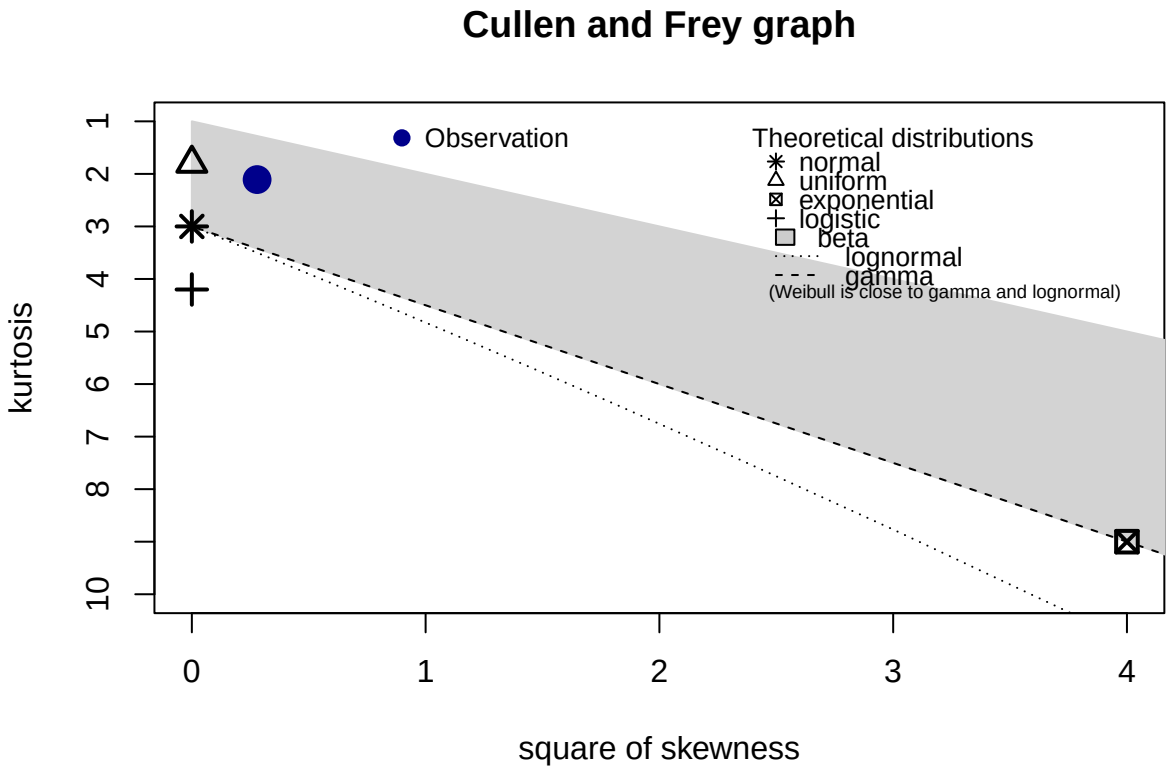
Section 1: Do exam scores differ significantly before and after the asychronous CURE?

```
# Fitting the data to a distribution
descdist(combined_scores$prescore, discrete = F)  #beta distributionn
```



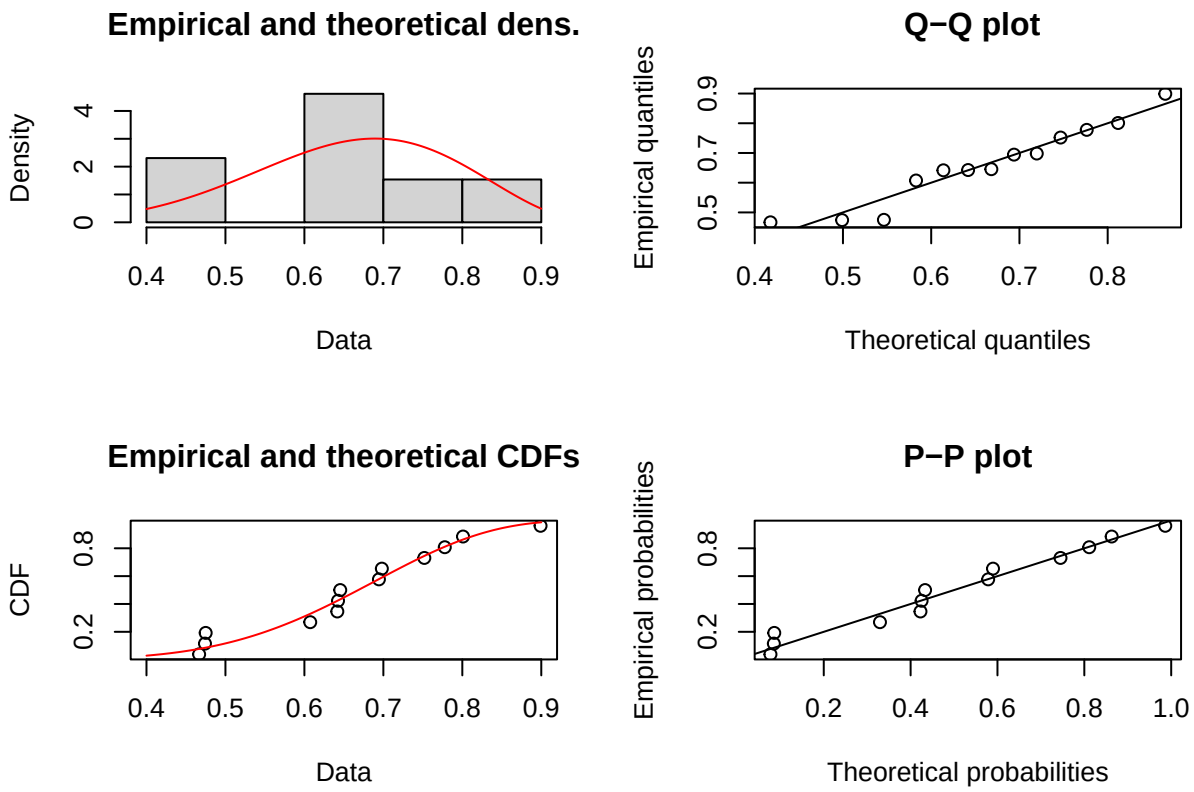

```
## summary statistics
## ------
## min:  0.4667   max:  0.8991
## median:  0.6454
## mean:  0.6596
## estimated sd:  0.1328
## estimated skewness:  -0.03891
## estimated kurtosis:  2.482
```

```
descdist(combined_scores$postscore, discrete = F)  #beta distribution
```

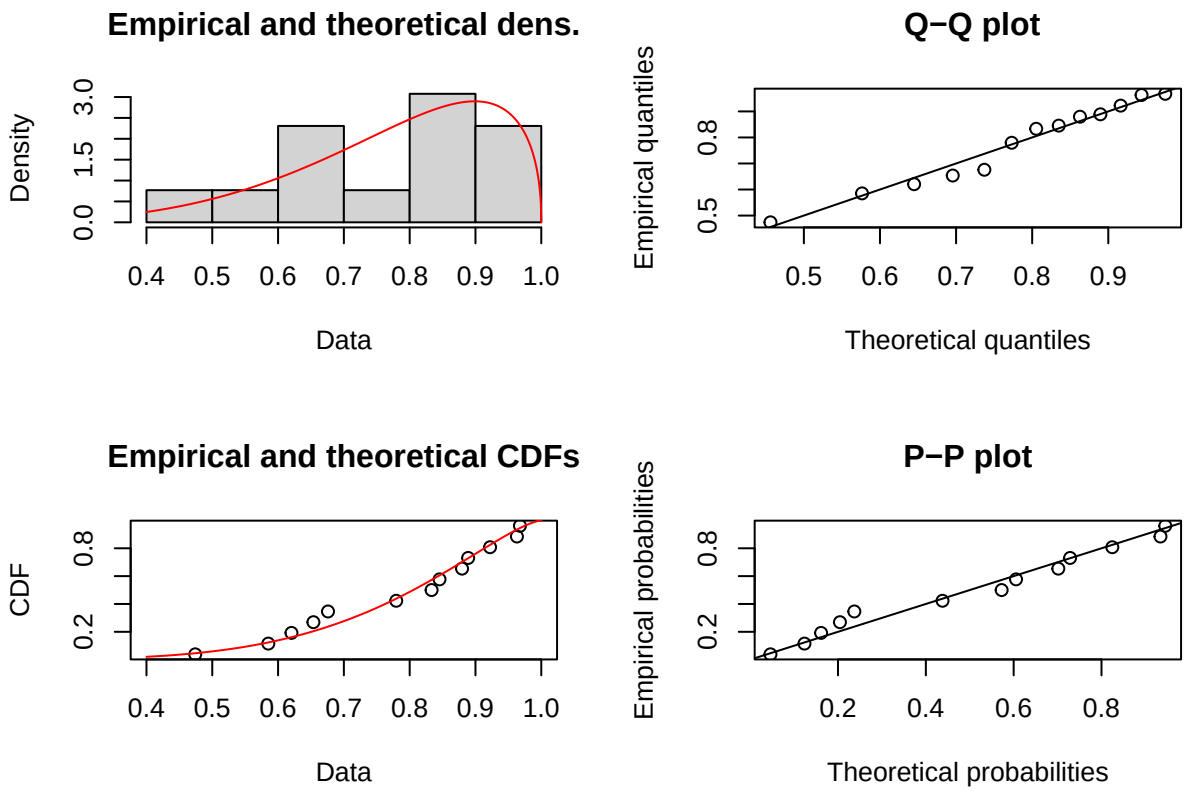



```
## summary statistics
## ------
## min:  0.4741   max:  0.9676
## median:  0.8333
## mean:  0.7761
## estimated sd:  0.1585
## estimated skewness:  -0.5284
## estimated kurtosis:  2.108
```

```
fit.beta_pre <- fitdist(combined_scores$prescore, "beta", method = "mme")
fit.beta_post <- fitdist(combined_scores$postscore, "beta", method = "mme")
plot(fit.beta_pre)
```



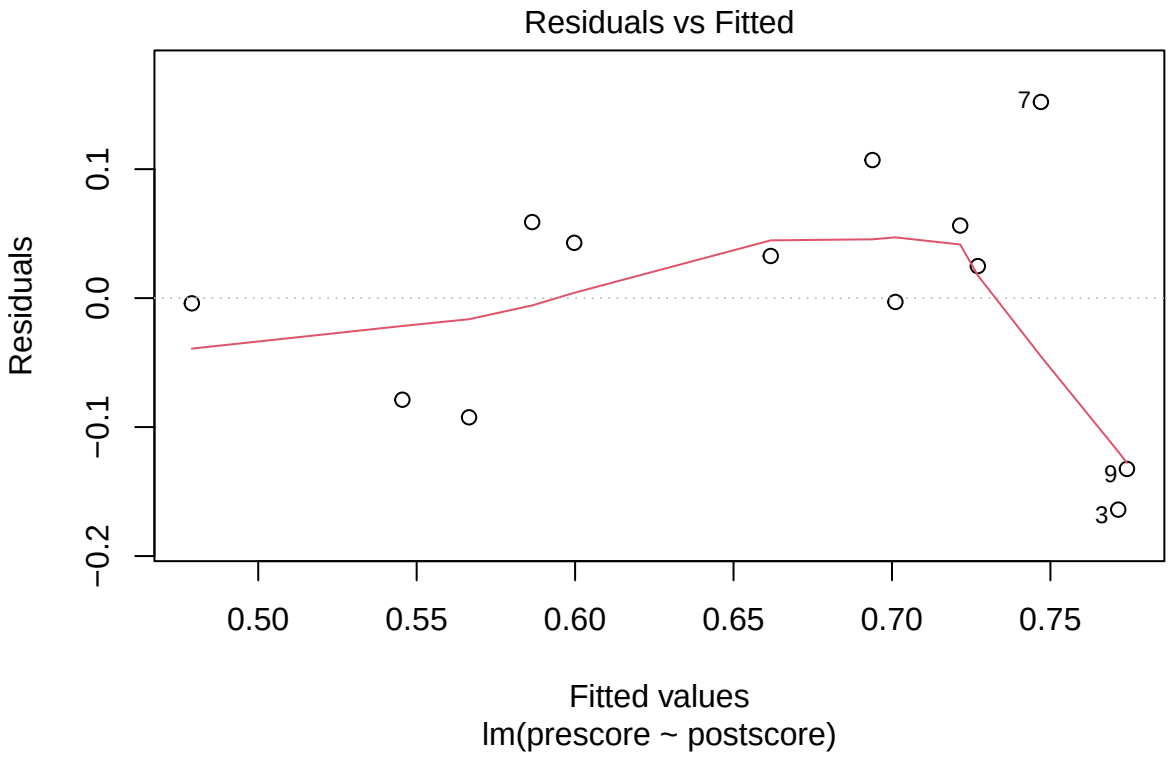

```
plot(fit.beta_post)
```

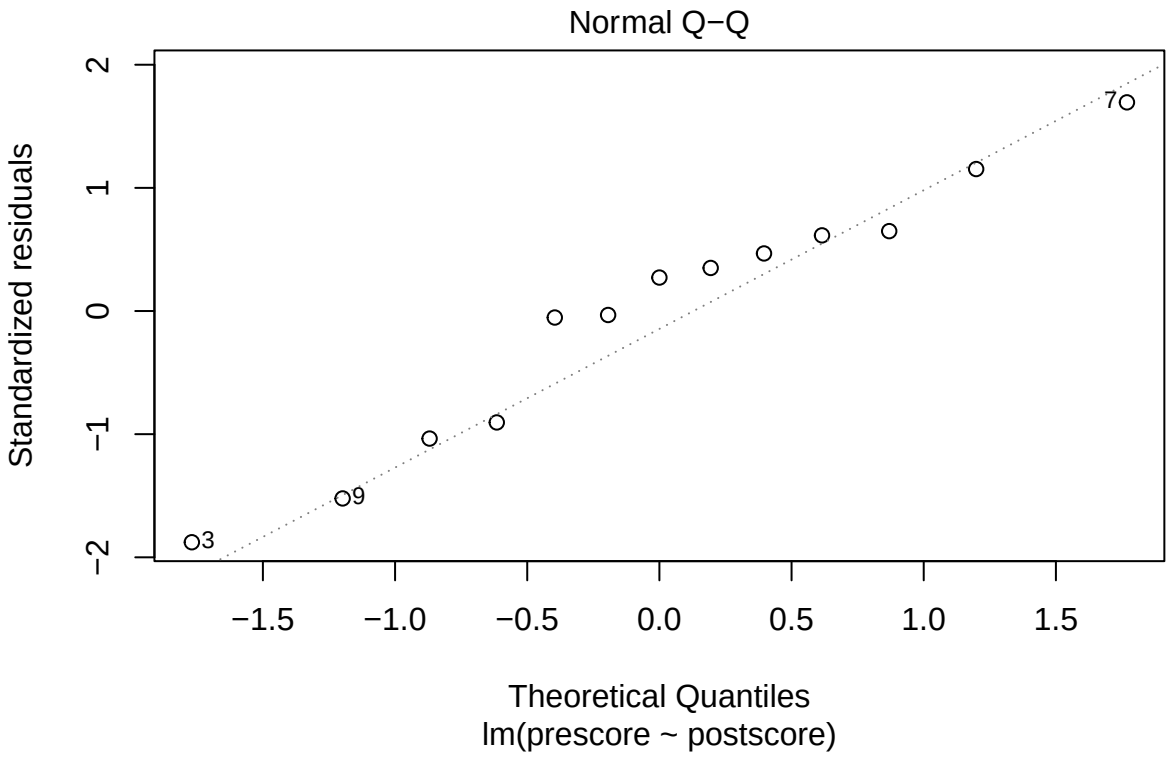


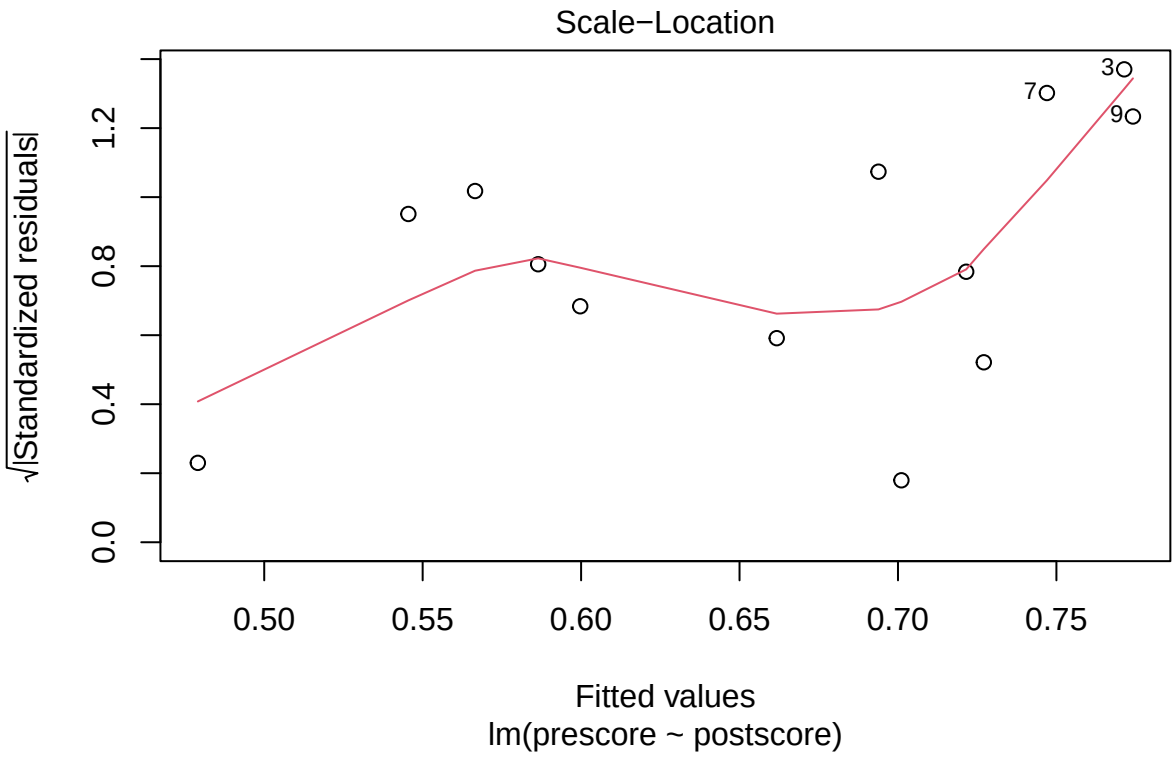

```
# Check the linear modeling of the prescores and postscores
overall_lm <- lm(formula = prescore ~ postscore, data = deltas_overall)
overall_lm
```

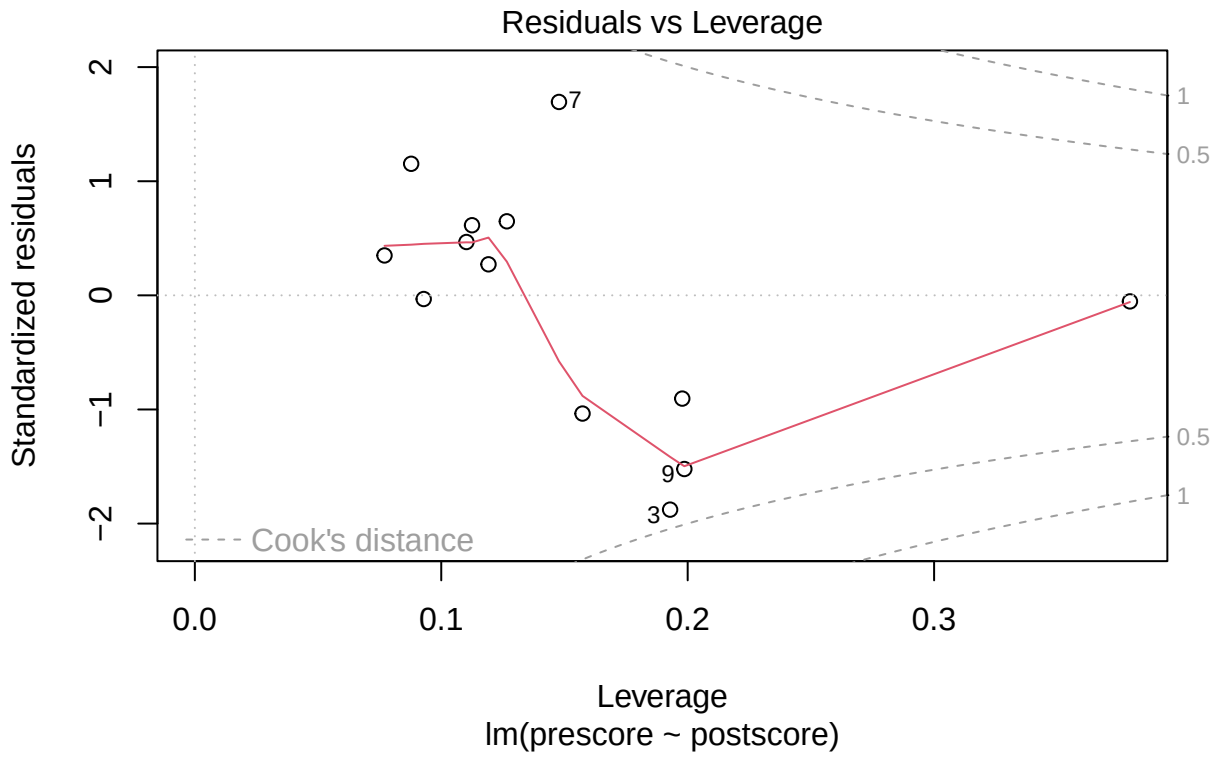
```
##
## Call:
## lm(formula = prescore ~ postscore, data = deltas_overall)
##
## Coefficients:
## (Intercept)    postscore
##       0.196        0.598
```

```
plot(overall_lm)
```


Residuals vs Fitted
Residuals
0.1
0.0
−0.1
−0.2
7
9
3
0.50
0.55
0.60
0.65
0.70
0.75
Fitted values
lm(prescore ~ postscore)


Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(prescore ~ postscore)
−2
−1
0
1
2
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
3
9
7


Scale−Location
√|Standardized residuals|
0.0
0.4
0.8
1.2
0.50
0.55
0.60
0.65
0.70
0.75
3
7
9
Fitted values
lm(prescore ~ postscore)



Exploratory data analysis

Using the parametric paired t-test, we assume that the data are normally distributed for our dataset.

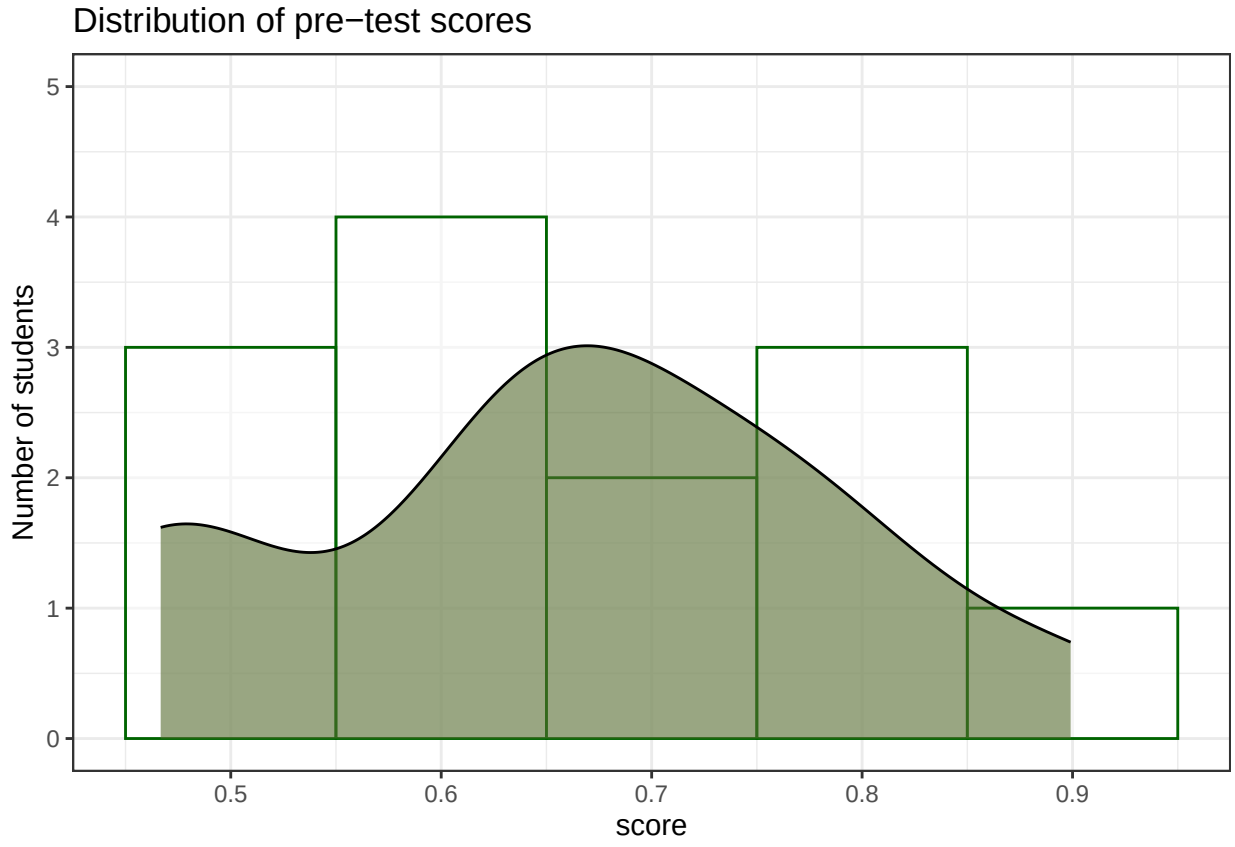
```
# Create a dataframe of the pre- and post-scores
histo_combined <- overall_scores

# Separate by pre and post scores
prescore <- histo_combined[1:13, ]
postscore <- histo_combined[14:26, ]

# summarize pre and post scores
summary(prescore)
```

```
##    student           assessment           score
##  Length:13          Length:13          Min.   :0.467
##  Class :character   Class :character   1st Qu.:0.607
##  Mode  :character   Mode  :character   Median :0.645
##                                        Mean   :0.660
##                                        3rd Qu.:0.752
##                                        Max.   :0.899
```

```
summary(postscore)
```

```
##    student            assessment            score
##  Length:13          Length:13          Min.   :0.474
##  Class :character   Class :character   1st Qu.:0.654
##  Mode  :character   Mode  :character   Median :0.833
##                                        Mean   :0.776
##                                        3rd Qu.:0.889
##                                        Max.   :0.968
```

```
## ================================================

# density plots with histograms per treatment to show
# distribution
dp_pre <- ggplot(prescore, aes(x = score)) + geom_histogram(data = prescore,
    fill = "white", col = "darkgreen", alpha = 0.5, binwidth = 0.1,
    bins = 30, position = "identity") + labs(title = "Distribution of pre-test scores",
    y = "Number of students") + geom_density(data = prescore,
    fill = "darkolivegreen", alpha = 0.6) + scale_x_continuous(breaks = seq(0,
    1, 0.1))
dp_pre + ylim(0, 5)
```




```
dp_post <- ggplot(postscore, aes(x = score)) + geom_histogram(data = postscore,
    fill = "white", alpha = 0.5, col = "darkorange2", binwidth = 0.1,
    bins = 30, position = "dodge") + labs(title = "Distribution of post-test scores",
    y = "Number of students") + geom_density(data = postscore,
    fill = "darkorange1", alpha = 0.6) + scale_x_continuous(breaks = seq(0,
```

```
    1, 0.1))
dp_post + ylim(0, 5)
```


```
# The null hypothesis for the Wilk-Shapiro test of
# normality is that the data are normally distributed.
shapiro.test(prescore$score)
```

Test for normal distribution using ShapiroWilk

```
##
##  Shapiro-Wilk normality test
##
## data:  prescore$score
## W = 0.94, p-value = 0.5
```

```
## There is not enough evidence to reject the null
## hypothesis. Therefore, each group follows a normal
## distribution.

shapiro.test(postscore$score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  postscore$score
## W = 0.93, p-value = 0.3
```

```
## There is not enough evidence to reject the null
## hypothesis. Therefore, each group follows a normal
## distribution.
```

Apply beta regression models

```
# Beta regression models Function to transform y values to
# be used on a betareg distribution
y.transf.betareg <- function(y) {
    n.obs <- sum(!is.na(y))
    (y * (n.obs - 1) + 0.5)/n.obs
}

# Are the post-recitation scores dependent on the
# pre-recitation scores?
effect_test_overall <- betareg(y.transf.betareg(prescore) ~ postscore,
    data = deltas_overall, link = "logit")
summary(effect_test_overall)
```

```
##
## Call:
## betareg(formula = y.transf.betareg(prescore) ~ postscore, data = deltas_overall,
##     link = "logit")
##
## Standardized weighted residuals 2:
##    Min     1Q Median     3Q    Max
## -1.932 -0.863  0.138  0.531  2.190
##
## Coefficients (mean model with logit link):
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)   -1.318      0.529   -2.49  0.01276 *
## postscore      2.518      0.682    3.69  0.00022 ***
##
## Phi coefficients (precision model with identity link):
##       Estimate Std. Error z value Pr(>|z|)
## (phi)     30.8       11.9    2.59   0.0097 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Type of estimator: ML (maximum likelihood)
## Log-likelihood:   14 on 3 Df
## Pseudo R-squared: 0.466
## Number of iterations: 22 (BFGS) + 1 (Fisher scoring)
```

Visualize paired outcomes data using box plots

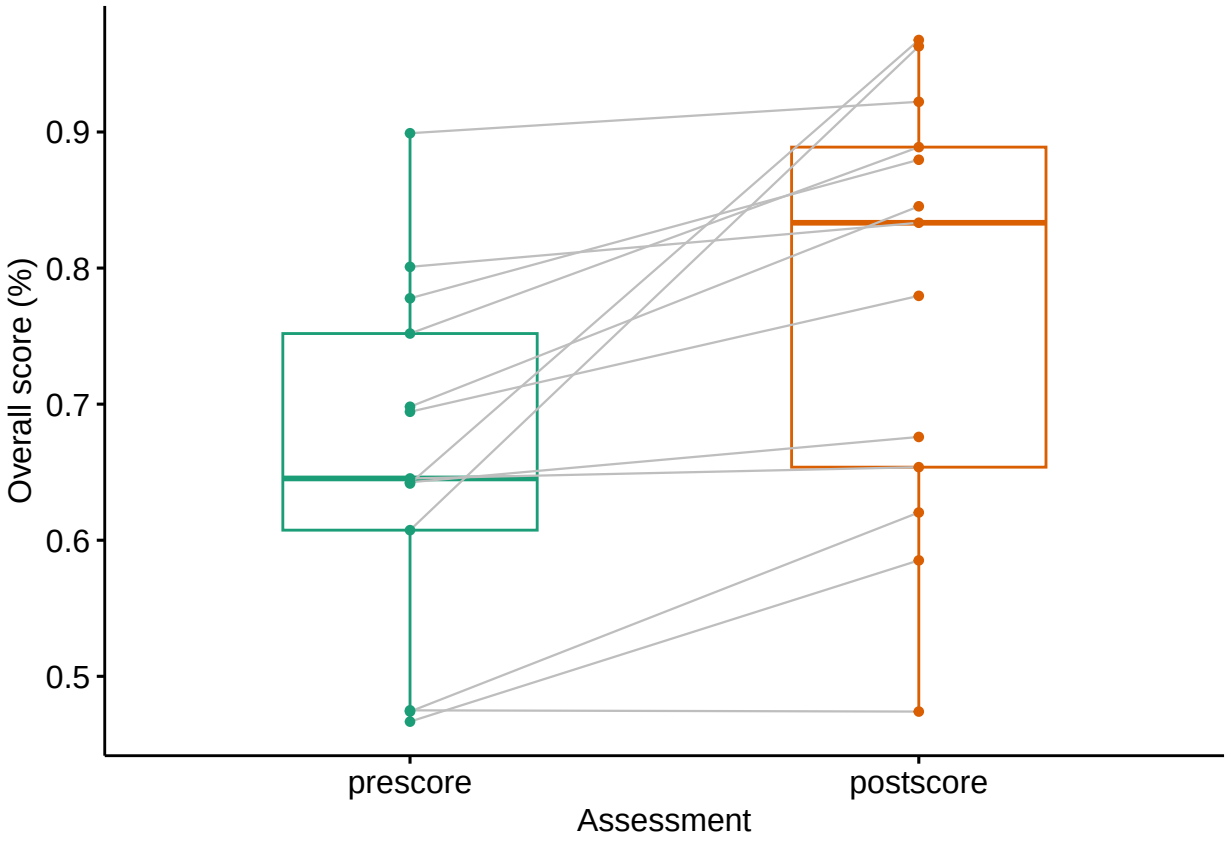
Use the boxplot to visualize differences in exam scores.

```
# Create a dataframe that is separated by group, score, and
# student
my_data <- data.frame(group = rep(c("prescore", "postscore"),
    each = 13), score = c(prescore$score, postscore$score), student = c(prescore$student,
    postscore$student))

# Compute summary statistics by groups using dplyr:
summary_overall <- group_by(my_data, group) %>%
    dplyr::summarize(count = n(), mean = mean(score, na.rm = TRUE),
        sd = sd(score, na.rm = TRUE))
summary_overall
```

```
## # A tibble: 2 x 4
##   group     count  mean    sd
##   <chr>     <int> <dbl> <dbl>
## 1 postscore    13 0.776 0.158
## 2 prescore     13 0.660 0.133
```

Paired boxplots of average assessment scores pre vs post test

```
pbp <- ggpaired(my_data, x = "group", y = "score", color = "group",
    line.color = "gray", line.size = 0.4, palette = "Dark2",
    xlab = "Assessment", ylab = "Overall score (%)") + theme(legend.position = "none")
pbp
```




```
ggsave(filename = "overall_score.pdf", plot = pbp)
```

```
## Saving 6.5 x 4.5 in image
```

The change in scores is visually evident by the histograms and the boxplots, but is it significant?

Check for signficance

Paired t-test Use the paired t-test on the dependent samples to test for significant differences in means between exam scores before and after the CURE

```
# Perform a paired samples t-test x,y: numeric vectors
# paired: a logical value specifying that we want to
# compute a paired t-test alternative: the alternative
# hypothesis. Allowed value is one of "two.sided"
# (default), "greater" or "less".

overall_ttest_all <- t.test(postscore$score, prescore$score,
    paired = TRUE, alternative = "two.sided")
overall_ttest_all
```

```
##
##  Paired t-test
##
```

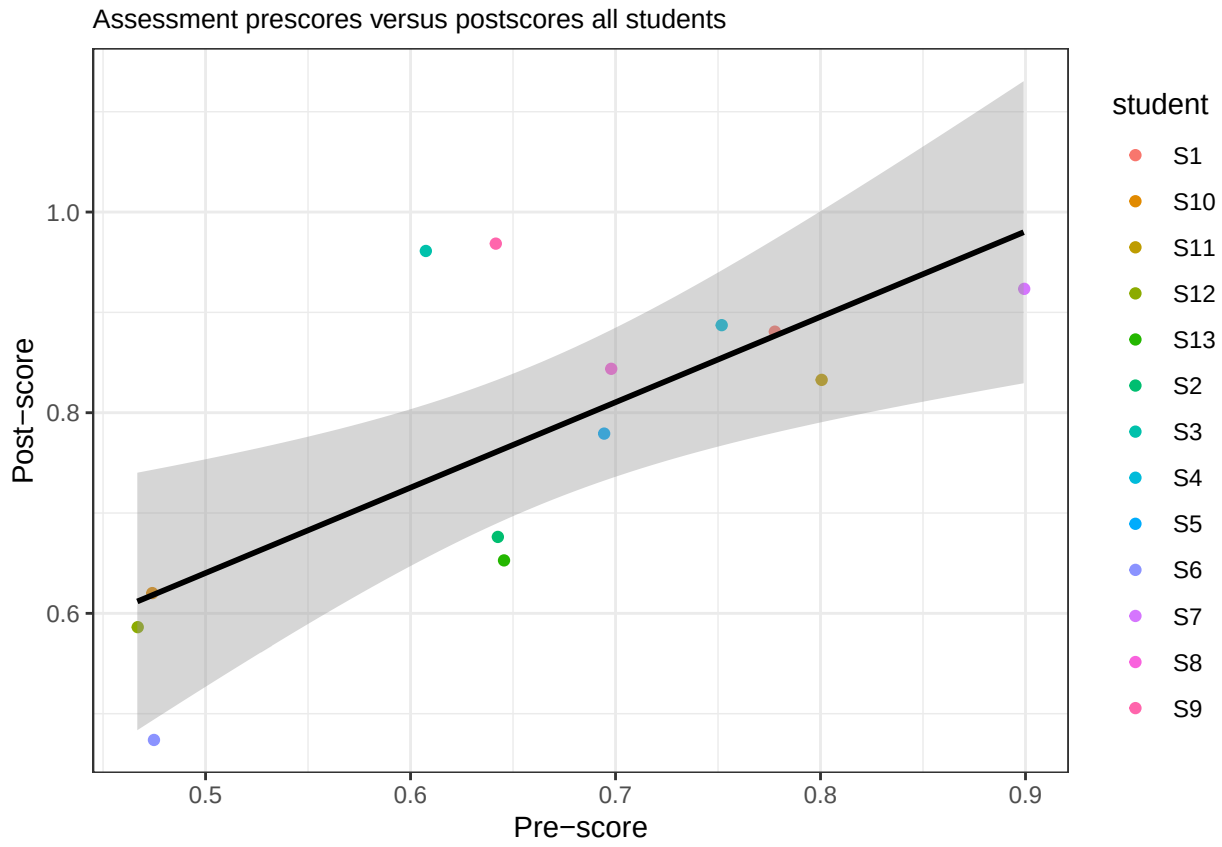
```
## data:  postscore$score and prescore$score
## t = 3.7, df = 12, p-value = 0.003
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  0.04828 0.18461
## sample estimates:
## mean difference
##          0.1164
```

Check effect size using Cohen's d Since the t-test calculated a p-value of 0.003, which is $< p = 0.05$, the overall score differences by individuals are significant. Next, effect size will express the magnitude of the significance to the population at large. - Small effect: 0.2 - Medium effect: 0.5 - Large effect: 0.8

Scatter plot of overall scores and correlation

```
# Scatter plot of overall scores
p1 <- ggplot(combined_scores, aes(x = prescore, y = postscore,
    color = student)) + geom_jitter() + geom_smooth(method = lm,
    color = "black", se = T) + theme(plot.title = element_text(size = 10)) +
    labs(title = "Assessment prescores versus postscores all students",
        x = "Pre-score", y = "Post-score")

p1
```

```
## `geom_smooth()` using formula = 'y ~ x'
```




```
summary(combined_scores)
```

```
##    student             prescore       postscore         delta
##  Length:13          Min.   :0.467   Min.   :0.474   Min.   :-0.0009
##  Class :character   1st Qu.:0.607   1st Qu.:0.654   1st Qu.: 0.0324
##  Mode  :character   Median :0.645   Median :0.833   Median : 0.1018
##                     Mean   :0.660   Mean   :0.776   Mean   : 0.1164
##                     3rd Qu.:0.752   3rd Qu.:0.889   3rd Qu.: 0.1463
##                     Max.   :0.899   Max.   :0.968   Max.   : 0.3556
```

```
# Check Pearson Correlation and test for significance
cor(combined_scores$prescore, combined_scores$postscore)
```

```
## [1] 0.7134
```

```
cor.test(combined_scores$prescore, combined_scores$postscore)
```

```
##
##  Pearson's product-moment correlation
##
## data:  combined_scores$prescore and combined_scores$postscore
## t = 3.4, df = 11, p-value = 0.006
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
```

```
##  0.2676 0.9076
## sample estimates:
##    cor
## 0.7134
```

Do scores differ by question and topic?

Biology, coding, professional development

```
# create the dataframes
# Import data for prescores by question
questions_pre <- read_csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B
```

```
## Rows: 234 Columns: 5
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (4): Question, Topic, Student, Type
## dbl (1): Score
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
View(questions_pre)

# Import data for prescores by question
questions_post <- read_csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22
```

```
## Rows: 234 Columns: 5
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (4): Question, Topic, Student, Type
## dbl (1): Score
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
View(questions_post)

# Alternative hypothesis accepted, true location shift is not = 0
df_questions_pre <- data.frame(score = questions_pre$Score,
                question = questions_pre$Question,
                topic = questions_pre$Topic,
                student = questions_pre$Student,
                assessment = "1_pre"
                )
df_questions_pre
```

```
##      score question   topic student assessment
## 1   0.5000       Q1 Biology      S1      1_pre
## 2   0.0000       Q2 Biology      S1      1_pre
## 3   1.0000       Q3 Biology      S1      1_pre
```

```
## 4   1.0000       Q4 Biology      S1      1_pre
## 5   1.0000       Q5 Biology      S1      1_pre
## 6   1.0000       Q6 Biology      S1      1_pre
## 7   1.0000       Q7 Biology      S1      1_pre
## 8   0.6667       Q8  Coding      S1      1_pre
## 9   1.0000       Q9  Coding      S1      1_pre
## 10  1.0000      Q10  Coding      S1      1_pre
## 11  0.3333      Q11  Coding      S1      1_pre
## 12  0.7500      Q12  Coding      S1      1_pre
## 13  0.0000      Q13  Coding      S1      1_pre
## 14  1.0000      Q14  Coding      S1      1_pre
## 15  1.0000      Q15 ProfDev      S1      1_pre
## 16  1.0000      Q16 ProfDev      S1      1_pre
## 17  1.0000      Q17 ProfDev      S1      1_pre
## 18  0.7500      Q18 ProfDev      S1      1_pre
## 19  1.0000       Q1 Biology      S2      1_pre
## 20  0.0000       Q2 Biology      S2      1_pre
## 21  0.4000       Q3 Biology      S2      1_pre
## 22  0.3333       Q4 Biology      S2      1_pre
## 23  0.5000       Q5 Biology      S2      1_pre
## 24  0.6667       Q6 Biology      S2      1_pre
## 25  1.0000       Q7 Biology      S2      1_pre
## 26  1.0000       Q8  Coding      S2      1_pre
## 27  0.5000       Q9  Coding      S2      1_pre
## 28  0.0000      Q10  Coding      S2      1_pre
## 29  0.6667      Q11  Coding      S2      1_pre
## 30  0.5000      Q12  Coding      S2      1_pre
## 31  1.0000      Q13  Coding      S2      1_pre
## 32  1.0000      Q14  Coding      S2      1_pre
## 33  0.0000      Q15 ProfDev      S2      1_pre
## 34  1.0000      Q16 ProfDev      S2      1_pre
## 35  1.0000      Q17 ProfDev      S2      1_pre
## 36  1.0000      Q18 ProfDev      S2      1_pre
## 37  0.2500       Q1 Biology      S3      1_pre
## 38  0.0000       Q2 Biology      S3      1_pre
## 39  0.6000       Q3 Biology      S3      1_pre
## 40  0.0000       Q4 Biology      S3      1_pre
## 41  0.1667       Q5 Biology      S3      1_pre
## 42  0.6667       Q6 Biology      S3      1_pre
## 43  1.0000       Q7 Biology      S3      1_pre
## 44  0.3333       Q8  Coding      S3      1_pre
## 45  1.0000       Q9  Coding      S3      1_pre
## 46  0.0000      Q10  Coding      S3      1_pre
## 47  0.6667      Q11  Coding      S3      1_pre
## 48  0.5000      Q12  Coding      S3      1_pre
## 49  1.0000      Q13  Coding      S3      1_pre
## 50  1.0000      Q14  Coding      S3      1_pre
## 51  1.0000      Q15 ProfDev      S3      1_pre
## 52  1.0000      Q16 ProfDev      S3      1_pre
## 53  1.0000      Q17 ProfDev      S3      1_pre
## 54  0.7500      Q18 ProfDev      S3      1_pre
## 55  1.0000       Q1 Biology      S4      1_pre
## 56  1.0000       Q2 Biology      S4      1_pre
## 57  0.8000       Q3 Biology      S4      1_pre
```

```
## 58  1.0000       Q4 Biology      S4      1_pre
## 59  0.1667       Q5 Biology      S4      1_pre
## 60  1.0000       Q6 Biology      S4      1_pre
## 61  1.0000       Q7 Biology      S4      1_pre
## 62  1.0000       Q8  Coding      S4      1_pre
## 63  0.5000       Q9  Coding      S4      1_pre
## 64  1.0000      Q10  Coding      S4      1_pre
## 65  1.0000      Q11  Coding      S4      1_pre
## 66  0.0000      Q12  Coding      S4      1_pre
## 67  1.0000      Q13  Coding      S4      1_pre
## 68  0.0000      Q14  Coding      S4      1_pre
## 69  0.4000      Q15 ProfDev      S4      1_pre
## 70  1.0000      Q16 ProfDev      S4      1_pre
## 71  0.6667      Q17 ProfDev      S4      1_pre
## 72  1.0000      Q18 ProfDev      S4      1_pre
## 73  0.7500       Q1 Biology      S5      1_pre
## 74  1.0000       Q2 Biology      S5      1_pre
## 75  0.6000       Q3 Biology      S5      1_pre
## 76  0.3333       Q4 Biology      S5      1_pre
## 77  0.5000       Q5 Biology      S5      1_pre
## 78  0.6667       Q6 Biology      S5      1_pre
## 79  1.0000       Q7 Biology      S5      1_pre
## 80  1.0000       Q8  Coding      S5      1_pre
## 81  0.5000       Q9  Coding      S5      1_pre
## 82  0.0000      Q10  Coding      S5      1_pre
## 83  0.6667      Q11  Coding      S5      1_pre
## 84  0.5000      Q12  Coding      S5      1_pre
## 85  1.0000      Q13  Coding      S5      1_pre
## 86  1.0000      Q14  Coding      S5      1_pre
## 87  0.4000      Q15 ProfDev      S5      1_pre
## 88  1.0000      Q16 ProfDev      S5      1_pre
## 89  0.8333      Q17 ProfDev      S5      1_pre
## 90  0.7500      Q18 ProfDev      S5      1_pre
## 91  0.2500       Q1 Biology      S6      1_pre
## 92  0.0000       Q2 Biology      S6      1_pre
## 93  0.4000       Q3 Biology      S6      1_pre
## 94  0.6667       Q4 Biology      S6      1_pre
## 95  1.0000       Q5 Biology      S6      1_pre
## 96  0.3333       Q6 Biology      S6      1_pre
## 97  1.0000       Q7 Biology      S6      1_pre
## 98  0.6667       Q8  Coding      S6      1_pre
## 99  0.5000       Q9  Coding      S6      1_pre
## 100 0.0000      Q10  Coding      S6      1_pre
## 101 0.3333      Q11  Coding      S6      1_pre
## 102 0.2500      Q12  Coding      S6      1_pre
## 103 0.0000      Q13  Coding      S6      1_pre
## 104 0.0000      Q14  Coding      S6      1_pre
## 105 0.4000      Q15 ProfDev      S6      1_pre
## 106 1.0000      Q16 ProfDev      S6      1_pre
## 107 1.0000      Q17 ProfDev      S6      1_pre
## 108 0.7500      Q18 ProfDev      S6      1_pre
## 109 1.0000       Q1 Biology      S7      1_pre
## 110 0.5000       Q2 Biology      S7      1_pre
## 111 1.0000       Q3 Biology      S7      1_pre
```

```
## 112 1.0000       Q4 Biology      S7      1_pre
## 113 1.0000       Q5 Biology      S7      1_pre
## 114 1.0000       Q6 Biology      S7      1_pre
## 115 1.0000       Q7 Biology      S7      1_pre
## 116 0.3333       Q8  Coding      S7      1_pre
## 117 1.0000       Q9  Coding      S7      1_pre
## 118 1.0000      Q10  Coding      S7      1_pre
## 119 1.0000      Q11  Coding      S7      1_pre
## 120 1.0000      Q12  Coding      S7      1_pre
## 121 1.0000      Q13  Coding      S7      1_pre
## 122 1.0000      Q14  Coding      S7      1_pre
## 123 0.6000      Q15 ProfDev      S7      1_pre
## 124 1.0000      Q16 ProfDev      S7      1_pre
## 125 1.0000      Q17 ProfDev      S7      1_pre
## 126 0.7500      Q18 ProfDev      S7      1_pre
## 127 1.0000       Q1 Biology      S8      1_pre
## 128 1.0000       Q2 Biology      S8      1_pre
## 129 0.4000       Q3 Biology      S8      1_pre
## 130 0.6667       Q4 Biology      S8      1_pre
## 131 1.0000       Q5 Biology      S8      1_pre
## 132 0.3333       Q6 Biology      S8      1_pre
## 133 0.0000       Q7 Biology      S8      1_pre
## 134 1.0000       Q8  Coding      S8      1_pre
## 135 1.0000       Q9  Coding      S8      1_pre
## 136 0.0000      Q10  Coding      S8      1_pre
## 137 0.6667      Q11  Coding      S8      1_pre
## 138 0.7500      Q12  Coding      S8      1_pre
## 139 0.0000      Q13  Coding      S8      1_pre
## 140 1.0000      Q14  Coding      S8      1_pre
## 141 1.0000      Q15 ProfDev      S8      1_pre
## 142 1.0000      Q16 ProfDev      S8      1_pre
## 143 1.0000      Q17 ProfDev      S8      1_pre
## 144 0.7500      Q18 ProfDev      S8      1_pre
## 145 1.0000       Q1 Biology      S9      1_pre
## 146 0.5000       Q2 Biology      S9      1_pre
## 147 0.8000       Q3 Biology      S9      1_pre
## 148 0.3333       Q4 Biology      S9      1_pre
## 149 1.0000       Q5 Biology      S9      1_pre
## 150 0.6667       Q6 Biology      S9      1_pre
## 151 0.0000       Q7 Biology      S9      1_pre
## 152 1.0000       Q8  Coding      S9      1_pre
## 153 0.5000       Q9  Coding      S9      1_pre
## 154 0.0000      Q10  Coding      S9      1_pre
## 155 1.0000      Q11  Coding      S9      1_pre
## 156 0.2500      Q12  Coding      S9      1_pre
## 157 0.0000      Q13  Coding      S9      1_pre
## 158 1.0000      Q14  Coding      S9      1_pre
## 159 1.0000      Q15 ProfDev      S9      1_pre
## 160 1.0000      Q16 ProfDev      S9      1_pre
## 161 1.0000      Q17 ProfDev      S9      1_pre
## 162 0.5000      Q18 ProfDev      S9      1_pre
## 163 0.5000       Q1 Biology     S10      1_pre
## 164 0.0000       Q2 Biology     S10      1_pre
## 165 0.8000       Q3 Biology     S10      1_pre
```

```
## 166 0.3333       Q4 Biology     S10      1_pre
## 167 0.5000       Q5 Biology     S10      1_pre
## 168 0.3333       Q6 Biology     S10      1_pre
## 169 0.0000       Q7 Biology     S10      1_pre
## 170 0.6667       Q8  Coding     S10      1_pre
## 171 1.0000       Q9  Coding     S10      1_pre
## 172 0.0000      Q10  Coding     S10      1_pre
## 173 0.6667      Q11  Coding     S10      1_pre
## 174 0.0000      Q12  Coding     S10      1_pre
## 175 1.0000      Q13  Coding     S10      1_pre
## 176 0.0000      Q14  Coding     S10      1_pre
## 177 0.4000      Q15 ProfDev     S10      1_pre
## 178 0.8333      Q16 ProfDev     S10      1_pre
## 179 0.5000      Q17 ProfDev     S10      1_pre
## 180 1.0000      Q18 ProfDev     S10      1_pre
## 181 1.0000       Q1 Biology     S11      1_pre
## 182 1.0000       Q2 Biology     S11      1_pre
## 183 1.0000       Q3 Biology     S11      1_pre
## 184 1.0000       Q4 Biology     S11      1_pre
## 185 0.1667       Q5 Biology     S11      1_pre
## 186 1.0000       Q6 Biology     S11      1_pre
## 187 1.0000       Q7 Biology     S11      1_pre
## 188 1.0000       Q8  Coding     S11      1_pre
## 189 1.0000       Q9  Coding     S11      1_pre
## 190 0.0000      Q10  Coding     S11      1_pre
## 191 1.0000      Q11  Coding     S11      1_pre
## 192 0.5000      Q12  Coding     S11      1_pre
## 193 1.0000      Q13  Coding     S11      1_pre
## 194 0.0000      Q14  Coding     S11      1_pre
## 195 1.0000      Q15 ProfDev     S11      1_pre
## 196 1.0000      Q16 ProfDev     S11      1_pre
## 197 1.0000      Q17 ProfDev     S11      1_pre
## 198 0.7500      Q18 ProfDev     S11      1_pre
## 199 0.2500       Q1 Biology     S12      1_pre
## 200 0.0000       Q2 Biology     S12      1_pre
## 201 0.4000       Q3 Biology     S12      1_pre
## 202 0.6667       Q4 Biology     S12      1_pre
## 203 0.5000       Q5 Biology     S12      1_pre
## 204 0.6667       Q6 Biology     S12      1_pre
## 205 0.0000       Q7 Biology     S12      1_pre
## 206 0.6667       Q8  Coding     S12      1_pre
## 207 0.0000       Q9  Coding     S12      1_pre
## 208 0.0000      Q10  Coding     S12      1_pre
## 209 0.0000      Q11  Coding     S12      1_pre
## 210 0.5000      Q12  Coding     S12      1_pre
## 211 1.0000      Q13  Coding     S12      1_pre
## 212 0.0000      Q14  Coding     S12      1_pre
## 213 1.0000      Q15 ProfDev     S12      1_pre
## 214 1.0000      Q16 ProfDev     S12      1_pre
## 215 1.0000      Q17 ProfDev     S12      1_pre
## 216 0.7500      Q18 ProfDev     S12      1_pre
## 217 0.5000       Q1 Biology     S13      1_pre
## 218 0.0000       Q2 Biology     S13      1_pre
## 219 1.0000       Q3 Biology     S13      1_pre
```

```
## 220 1.0000       Q4 Biology     S13      1_pre
## 221 1.0000       Q5 Biology     S13      1_pre
## 222 0.6667       Q6 Biology     S13      1_pre
## 223 0.0000       Q7 Biology     S13      1_pre
## 224 1.0000       Q8  Coding     S13      1_pre
## 225 1.0000       Q9  Coding     S13      1_pre
## 226 0.0000      Q10  Coding     S13      1_pre
## 227 1.0000      Q11  Coding     S13      1_pre
## 228 0.2500      Q12  Coding     S13      1_pre
## 229 0.0000      Q13  Coding     S13      1_pre
## 230 1.0000      Q14  Coding     S13      1_pre
## 231 0.2000      Q15 ProfDev     S13      1_pre
## 232 1.0000      Q16 ProfDev     S13      1_pre
## 233 1.0000      Q17 ProfDev     S13      1_pre
## 234 1.0000      Q18 ProfDev     S13      1_pre
```

```
df_questions_post <- data.frame(score = questions_post$Score,
                question = questions_post$Question,
                topic = questions_post$Topic,
                student = questions_post$Student,
                assessment = "2_post"
                )
df_questions_post
```

```
##      score question   topic student assessment
## 1   0.5000       Q1 Biology      S1     2_post
## 2   0.5000       Q2 Biology      S1     2_post
## 3   1.0000       Q3 Biology      S1     2_post
## 4   0.6667       Q4 Biology      S1     2_post
## 5   1.0000       Q5 Biology      S1     2_post
## 6   1.0000       Q6 Biology      S1     2_post
## 7   1.0000       Q7 Biology      S1     2_post
## 8   0.6667       Q8  Coding      S1     2_post
## 9   1.0000       Q9  Coding      S1     2_post
## 10  1.0000      Q10  Coding      S1     2_post
## 11  1.0000      Q11  Coding      S1     2_post
## 12  0.5000      Q12  Coding      S1     2_post
## 13  1.0000      Q13  Coding      S1     2_post
## 14  1.0000      Q14  Coding      S1     2_post
## 15  1.0000      Q15 ProfDev      S1     2_post
## 16  1.0000      Q16 ProfDev      S1     2_post
## 17  1.0000      Q17 ProfDev      S1     2_post
## 18  1.0000      Q18 ProfDev      S1     2_post
## 19  0.7500       Q1 Biology      S2     2_post
## 20  1.0000       Q2 Biology      S2     2_post
## 21  0.8000       Q3 Biology      S2     2_post
## 22  0.3333       Q4 Biology      S2     2_post
## 23  0.6667       Q5 Biology      S2     2_post
## 24  0.6667       Q6 Biology      S2     2_post
## 25  1.0000       Q7 Biology      S2     2_post
## 26  1.0000       Q8  Coding      S2     2_post
## 27  0.5000       Q9  Coding      S2     2_post
## 28  1.0000      Q10  Coding      S2     2_post
## 29  0.0000      Q11  Coding      S2     2_post
```

```
## 30  0.5000      Q12  Coding      S2     2_post
## 31  1.0000      Q13  Coding      S2     2_post
## 32  0.0000      Q14  Coding      S2     2_post
## 33  0.2000      Q15 ProfDev      S2     2_post
## 34  1.0000      Q16 ProfDev      S2     2_post
## 35  1.0000      Q17 ProfDev      S2     2_post
## 36  0.7500      Q18 ProfDev      S2     2_post
## 37  1.0000       Q1 Biology      S3     2_post
## 38  1.0000       Q2 Biology      S3     2_post
## 39  1.0000       Q3 Biology      S3     2_post
## 40  1.0000       Q4 Biology      S3     2_post
## 41  1.0000       Q5 Biology      S3     2_post
## 42  1.0000       Q6 Biology      S3     2_post
## 43  1.0000       Q7 Biology      S3     2_post
## 44  0.3333       Q8  Coding      S3     2_post
## 45  1.0000       Q9  Coding      S3     2_post
## 46  1.0000      Q10  Coding      S3     2_post
## 47  1.0000      Q11  Coding      S3     2_post
## 48  1.0000      Q12  Coding      S3     2_post
## 49  1.0000      Q13  Coding      S3     2_post
## 50  1.0000      Q14  Coding      S3     2_post
## 51  1.0000      Q15 ProfDev      S3     2_post
## 52  1.0000      Q16 ProfDev      S3     2_post
## 53  1.0000      Q17 ProfDev      S3     2_post
## 54  1.0000      Q18 ProfDev      S3     2_post
## 55  1.0000       Q1 Biology      S4     2_post
## 56  1.0000       Q2 Biology      S4     2_post
## 57  1.0000       Q3 Biology      S4     2_post
## 58  0.6667       Q4 Biology      S4     2_post
## 59  1.0000       Q5 Biology      S4     2_post
## 60  1.0000       Q6 Biology      S4     2_post
## 61  1.0000       Q7 Biology      S4     2_post
## 62  1.0000       Q8  Coding      S4     2_post
## 63  0.5000       Q9  Coding      S4     2_post
## 64  1.0000      Q10  Coding      S4     2_post
## 65  0.3333      Q11  Coding      S4     2_post
## 66  0.7500      Q12  Coding      S4     2_post
## 67  1.0000      Q13  Coding      S4     2_post
## 68  1.0000      Q14  Coding      S4     2_post
## 69  1.0000      Q15 ProfDev      S4     2_post
## 70  1.0000      Q16 ProfDev      S4     2_post
## 71  1.0000      Q17 ProfDev      S4     2_post
## 72  0.7500      Q18 ProfDev      S4     2_post
## 73  0.7500       Q1 Biology      S5     2_post
## 74  1.0000       Q2 Biology      S5     2_post
## 75  0.8000       Q3 Biology      S5     2_post
## 76  0.3333       Q4 Biology      S5     2_post
## 77  1.0000       Q5 Biology      S5     2_post
## 78  0.6667       Q6 Biology      S5     2_post
## 79  1.0000       Q7 Biology      S5     2_post
## 80  0.3333       Q8  Coding      S5     2_post
## 81  0.5000       Q9  Coding      S5     2_post
## 82  1.0000      Q10  Coding      S5     2_post
## 83  1.0000      Q11  Coding      S5     2_post
```

```
## 84  0.5000      Q12  Coding      S5     2_post
## 85  1.0000      Q13  Coding      S5     2_post
## 86  1.0000      Q14  Coding      S5     2_post
## 87  0.4000      Q15 ProfDev      S5     2_post
## 88  1.0000      Q16 ProfDev      S5     2_post
## 89  1.0000      Q17 ProfDev      S5     2_post
## 90  0.7500      Q18 ProfDev      S5     2_post
## 91  0.5000       Q1 Biology      S6     2_post
## 92  1.0000       Q2 Biology      S6     2_post
## 93  1.0000       Q3 Biology      S6     2_post
## 94  0.6667       Q4 Biology      S6     2_post
## 95  0.0000       Q5 Biology      S6     2_post
## 96  0.6667       Q6 Biology      S6     2_post
## 97  0.0000       Q7 Biology      S6     2_post
## 98  0.6667       Q8  Coding      S6     2_post
## 99  0.5000       Q9  Coding      S6     2_post
## 100 0.0000      Q10  Coding      S6     2_post
## 101 0.3333      Q11  Coding      S6     2_post
## 102 0.2500      Q12  Coding      S6     2_post
## 103 0.0000      Q13  Coding      S6     2_post
## 104 0.0000      Q14  Coding      S6     2_post
## 105 0.2000      Q15 ProfDev      S6     2_post
## 106 1.0000      Q16 ProfDev      S6     2_post
## 107 1.0000      Q17 ProfDev      S6     2_post
## 108 0.7500      Q18 ProfDev      S6     2_post
## 109 1.0000       Q1 Biology      S7     2_post
## 110 1.0000       Q2 Biology      S7     2_post
## 111 1.0000       Q3 Biology      S7     2_post
## 112 1.0000       Q4 Biology      S7     2_post
## 113 1.0000       Q5 Biology      S7     2_post
## 114 1.0000       Q6 Biology      S7     2_post
## 115 1.0000       Q7 Biology      S7     2_post
## 116 0.0000       Q8  Coding      S7     2_post
## 117 1.0000       Q9  Coding      S7     2_post
## 118 1.0000      Q10  Coding      S7     2_post
## 119 1.0000      Q11  Coding      S7     2_post
## 120 1.0000      Q12  Coding      S7     2_post
## 121 1.0000      Q13  Coding      S7     2_post
## 122 1.0000      Q14  Coding      S7     2_post
## 123 0.6000      Q15 ProfDev      S7     2_post
## 124 1.0000      Q16 ProfDev      S7     2_post
## 125 1.0000      Q17 ProfDev      S7     2_post
## 126 1.0000      Q18 ProfDev      S7     2_post
## 127 1.0000       Q1 Biology      S8     2_post
## 128 1.0000       Q2 Biology      S8     2_post
## 129 0.8000       Q3 Biology      S8     2_post
## 130 0.6667       Q4 Biology      S8     2_post
## 131 0.8333       Q5 Biology      S8     2_post
## 132 1.0000       Q6 Biology      S8     2_post
## 133 1.0000       Q7 Biology      S8     2_post
## 134 0.6667       Q8  Coding      S8     2_post
## 135 0.5000       Q9  Coding      S8     2_post
## 136 0.0000      Q10  Coding      S8     2_post
## 137 1.0000      Q11  Coding      S8     2_post
```

```
## 138 1.0000      Q12  Coding      S8     2_post
## 139 1.0000      Q13  Coding      S8     2_post
## 140 1.0000      Q14  Coding      S8     2_post
## 141 1.0000      Q15 ProfDev      S8     2_post
## 142 1.0000      Q16 ProfDev      S8     2_post
## 143 1.0000      Q17 ProfDev      S8     2_post
## 144 0.7500      Q18 ProfDev      S8     2_post
## 145 1.0000       Q1 Biology      S9     2_post
## 146 1.0000       Q2 Biology      S9     2_post
## 147 1.0000       Q3 Biology      S9     2_post
## 148 0.6667       Q4 Biology      S9     2_post
## 149 1.0000       Q5 Biology      S9     2_post
## 150 1.0000       Q6 Biology      S9     2_post
## 151 1.0000       Q7 Biology      S9     2_post
## 152 1.0000       Q8  Coding      S9     2_post
## 153 1.0000       Q9  Coding      S9     2_post
## 154 1.0000      Q10  Coding      S9     2_post
## 155 1.0000      Q11  Coding      S9     2_post
## 156 1.0000      Q12  Coding      S9     2_post
## 157 1.0000      Q13  Coding      S9     2_post
## 158 1.0000      Q14  Coding      S9     2_post
## 159 1.0000      Q15 ProfDev      S9     2_post
## 160 1.0000      Q16 ProfDev      S9     2_post
## 161 1.0000      Q17 ProfDev      S9     2_post
## 162 0.7500      Q18 ProfDev      S9     2_post
## 163 0.7500       Q1 Biology     S10     2_post
## 164 1.0000       Q2 Biology     S10     2_post
## 165 1.0000       Q3 Biology     S10     2_post
## 166 0.0000       Q4 Biology     S10     2_post
## 167 0.3333       Q5 Biology     S10     2_post
## 168 1.0000       Q6 Biology     S10     2_post
## 169 0.0000       Q7 Biology     S10     2_post
## 170 1.0000       Q8  Coding     S10     2_post
## 171 1.0000       Q9  Coding     S10     2_post
## 172 0.0000      Q10  Coding     S10     2_post
## 173 1.0000      Q11  Coding     S10     2_post
## 174 0.5000      Q12  Coding     S10     2_post
## 175 0.0000      Q13  Coding     S10     2_post
## 176 0.0000      Q14  Coding     S10     2_post
## 177 1.0000      Q15 ProfDev     S10     2_post
## 178 0.8333      Q16 ProfDev     S10     2_post
## 179 1.0000      Q17 ProfDev     S10     2_post
## 180 0.7500      Q18 ProfDev     S10     2_post
## 181 1.0000       Q1 Biology     S11     2_post
## 182 1.0000       Q2 Biology     S11     2_post
## 183 1.0000       Q3 Biology     S11     2_post
## 184 0.3333       Q4 Biology     S11     2_post
## 185 1.0000       Q5 Biology     S11     2_post
## 186 1.0000       Q6 Biology     S11     2_post
## 187 1.0000       Q7 Biology     S11     2_post
## 188 1.0000       Q8  Coding     S11     2_post
## 189 0.5000       Q9  Coding     S11     2_post
## 190 1.0000      Q10  Coding     S11     2_post
## 191 0.6667      Q11  Coding     S11     2_post
```

```
## 192 0.5000      Q12  Coding     S11     2_post
## 193 1.0000      Q13  Coding     S11     2_post
## 194 0.0000      Q14  Coding     S11     2_post
## 195 1.0000      Q15 ProfDev     S11     2_post
## 196 1.0000      Q16 ProfDev     S11     2_post
## 197 1.0000      Q17 ProfDev     S11     2_post
## 198 1.0000      Q18 ProfDev     S11     2_post
## 199 0.5000       Q1 Biology     S12     2_post
## 200 0.0000       Q2 Biology     S12     2_post
## 201 0.6000       Q3 Biology     S12     2_post
## 202 0.6667       Q4 Biology     S12     2_post
## 203 0.1667       Q5 Biology     S12     2_post
## 204 0.3333       Q6 Biology     S12     2_post
## 205 1.0000       Q7 Biology     S12     2_post
## 206 1.0000       Q8  Coding     S12     2_post
## 207 1.0000       Q9  Coding     S12     2_post
## 208 1.0000      Q10  Coding     S12     2_post
## 209 0.6667      Q11  Coding     S12     2_post
## 210 0.5000      Q12  Coding     S12     2_post
## 211 0.0000      Q13  Coding     S12     2_post
## 212 0.0000      Q14  Coding     S12     2_post
## 213 0.6000      Q15 ProfDev     S12     2_post
## 214 1.0000      Q16 ProfDev     S12     2_post
## 215 1.0000      Q17 ProfDev     S12     2_post
## 216 0.5000      Q18 ProfDev     S12     2_post
## 217 0.7500       Q1 Biology     S14     2_post
## 218 0.0000       Q2 Biology     S14     2_post
## 219 1.0000       Q3 Biology     S14     2_post
## 220 0.0000       Q4 Biology     S14     2_post
## 221 1.0000       Q5 Biology     S14     2_post
## 222 0.6667       Q6 Biology     S14     2_post
## 223 1.0000       Q7 Biology     S14     2_post
## 224 0.3333       Q8  Coding     S14     2_post
## 225 0.5000       Q9  Coding     S14     2_post
## 226 1.0000      Q10  Coding     S14     2_post
## 227 0.6667      Q11  Coding     S14     2_post
## 228 0.5000      Q12  Coding     S14     2_post
## 229 0.0000      Q13  Coding     S14     2_post
## 230 1.0000      Q14  Coding     S14     2_post
## 231 0.6000      Q15 ProfDev     S14     2_post
## 232 1.0000      Q16 ProfDev     S14     2_post
## 233 1.0000      Q17 ProfDev     S14     2_post
## 234 0.7500      Q18 ProfDev     S14     2_post
```

```r
# create the dataframe
question_data <- data.frame(
  group = c(df_questions_pre$assessment, df_questions_post$assessment),
  score = c(df_questions_pre$score, df_questions_post$score),
  question = c(df_questions_pre$question, df_questions_post$question),
  topic = c(df_questions_pre$topic, df_questions_post$topic),
  student = c(df_questions_pre$student, df_questions_post$student))

# view the df
question_data
```

```
##      group  score question   topic student
## 1    1_pre 0.5000       Q1 Biology      S1
## 2    1_pre 0.0000       Q2 Biology      S1
## 3    1_pre 1.0000       Q3 Biology      S1
## 4    1_pre 1.0000       Q4 Biology      S1
## 5    1_pre 1.0000       Q5 Biology      S1
## 6    1_pre 1.0000       Q6 Biology      S1
## 7    1_pre 1.0000       Q7 Biology      S1
## 8    1_pre 0.6667       Q8  Coding      S1
## 9    1_pre 1.0000       Q9  Coding      S1
## 10   1_pre 1.0000      Q10  Coding      S1
## 11   1_pre 0.3333      Q11  Coding      S1
## 12   1_pre 0.7500      Q12  Coding      S1
## 13   1_pre 0.0000      Q13  Coding      S1
## 14   1_pre 1.0000      Q14  Coding      S1
## 15   1_pre 1.0000      Q15 ProfDev      S1
## 16   1_pre 1.0000      Q16 ProfDev      S1
## 17   1_pre 1.0000      Q17 ProfDev      S1
## 18   1_pre 0.7500      Q18 ProfDev      S1
## 19   1_pre 1.0000       Q1 Biology      S2
## 20   1_pre 0.0000       Q2 Biology      S2
## 21   1_pre 0.4000       Q3 Biology      S2
## 22   1_pre 0.3333       Q4 Biology      S2
## 23   1_pre 0.5000       Q5 Biology      S2
## 24   1_pre 0.6667       Q6 Biology      S2
## 25   1_pre 1.0000       Q7 Biology      S2
## 26   1_pre 1.0000       Q8  Coding      S2
## 27   1_pre 0.5000       Q9  Coding      S2
## 28   1_pre 0.0000      Q10  Coding      S2
## 29   1_pre 0.6667      Q11  Coding      S2
## 30   1_pre 0.5000      Q12  Coding      S2
## 31   1_pre 1.0000      Q13  Coding      S2
## 32   1_pre 1.0000      Q14  Coding      S2
## 33   1_pre 0.0000      Q15 ProfDev      S2
## 34   1_pre 1.0000      Q16 ProfDev      S2
## 35   1_pre 1.0000      Q17 ProfDev      S2
## 36   1_pre 1.0000      Q18 ProfDev      S2
## 37   1_pre 0.2500       Q1 Biology      S3
## 38   1_pre 0.0000       Q2 Biology      S3
## 39   1_pre 0.6000       Q3 Biology      S3
## 40   1_pre 0.0000       Q4 Biology      S3
## 41   1_pre 0.1667       Q5 Biology      S3
## 42   1_pre 0.6667       Q6 Biology      S3
## 43   1_pre 1.0000       Q7 Biology      S3
## 44   1_pre 0.3333       Q8  Coding      S3
## 45   1_pre 1.0000       Q9  Coding      S3
## 46   1_pre 0.0000      Q10  Coding      S3
## 47   1_pre 0.6667      Q11  Coding      S3
## 48   1_pre 0.5000      Q12  Coding      S3
## 49   1_pre 1.0000      Q13  Coding      S3
## 50   1_pre 1.0000      Q14  Coding      S3
## 51   1_pre 1.0000      Q15 ProfDev      S3
## 52   1_pre 1.0000      Q16 ProfDev      S3
## 53   1_pre 1.0000      Q17 ProfDev      S3
```

```
## 54   1_pre 0.7500      Q18 ProfDev      S3
## 55   1_pre 1.0000       Q1 Biology      S4
## 56   1_pre 1.0000       Q2 Biology      S4
## 57   1_pre 0.8000       Q3 Biology      S4
## 58   1_pre 1.0000       Q4 Biology      S4
## 59   1_pre 0.1667       Q5 Biology      S4
## 60   1_pre 1.0000       Q6 Biology      S4
## 61   1_pre 1.0000       Q7 Biology      S4
## 62   1_pre 1.0000       Q8  Coding      S4
## 63   1_pre 0.5000       Q9  Coding      S4
## 64   1_pre 1.0000      Q10  Coding      S4
## 65   1_pre 1.0000      Q11  Coding      S4
## 66   1_pre 0.0000      Q12  Coding      S4
## 67   1_pre 1.0000      Q13  Coding      S4
## 68   1_pre 0.0000      Q14  Coding      S4
## 69   1_pre 0.4000      Q15 ProfDev      S4
## 70   1_pre 1.0000      Q16 ProfDev      S4
## 71   1_pre 0.6667      Q17 ProfDev      S4
## 72   1_pre 1.0000      Q18 ProfDev      S4
## 73   1_pre 0.7500       Q1 Biology      S5
## 74   1_pre 1.0000       Q2 Biology      S5
## 75   1_pre 0.6000       Q3 Biology      S5
## 76   1_pre 0.3333       Q4 Biology      S5
## 77   1_pre 0.5000       Q5 Biology      S5
## 78   1_pre 0.6667       Q6 Biology      S5
## 79   1_pre 1.0000       Q7 Biology      S5
## 80   1_pre 1.0000       Q8  Coding      S5
## 81   1_pre 0.5000       Q9  Coding      S5
## 82   1_pre 0.0000      Q10  Coding      S5
## 83   1_pre 0.6667      Q11  Coding      S5
## 84   1_pre 0.5000      Q12  Coding      S5
## 85   1_pre 1.0000      Q13  Coding      S5
## 86   1_pre 1.0000      Q14  Coding      S5
## 87   1_pre 0.4000      Q15 ProfDev      S5
## 88   1_pre 1.0000      Q16 ProfDev      S5
## 89   1_pre 0.8333      Q17 ProfDev      S5
## 90   1_pre 0.7500      Q18 ProfDev      S5
## 91   1_pre 0.2500       Q1 Biology      S6
## 92   1_pre 0.0000       Q2 Biology      S6
## 93   1_pre 0.4000       Q3 Biology      S6
## 94   1_pre 0.6667       Q4 Biology      S6
## 95   1_pre 1.0000       Q5 Biology      S6
## 96   1_pre 0.3333       Q6 Biology      S6
## 97   1_pre 1.0000       Q7 Biology      S6
## 98   1_pre 0.6667       Q8  Coding      S6
## 99   1_pre 0.5000       Q9  Coding      S6
## 100  1_pre 0.0000      Q10  Coding      S6
## 101  1_pre 0.3333      Q11  Coding      S6
## 102  1_pre 0.2500      Q12  Coding      S6
## 103  1_pre 0.0000      Q13  Coding      S6
## 104  1_pre 0.0000      Q14  Coding      S6
## 105  1_pre 0.4000      Q15 ProfDev      S6
## 106  1_pre 1.0000      Q16 ProfDev      S6
## 107  1_pre 1.0000      Q17 ProfDev      S6
```

```
## 108  1_pre 0.7500      Q18 ProfDev      S6
## 109  1_pre 1.0000       Q1 Biology      S7
## 110  1_pre 0.5000       Q2 Biology      S7
## 111  1_pre 1.0000       Q3 Biology      S7
## 112  1_pre 1.0000       Q4 Biology      S7
## 113  1_pre 1.0000       Q5 Biology      S7
## 114  1_pre 1.0000       Q6 Biology      S7
## 115  1_pre 1.0000       Q7 Biology      S7
## 116  1_pre 0.3333       Q8  Coding      S7
## 117  1_pre 1.0000       Q9  Coding      S7
## 118  1_pre 1.0000      Q10  Coding      S7
## 119  1_pre 1.0000      Q11  Coding      S7
## 120  1_pre 1.0000      Q12  Coding      S7
## 121  1_pre 1.0000      Q13  Coding      S7
## 122  1_pre 1.0000      Q14  Coding      S7
## 123  1_pre 0.6000      Q15 ProfDev      S7
## 124  1_pre 1.0000      Q16 ProfDev      S7
## 125  1_pre 1.0000      Q17 ProfDev      S7
## 126  1_pre 0.7500      Q18 ProfDev      S7
## 127  1_pre 1.0000       Q1 Biology      S8
## 128  1_pre 1.0000       Q2 Biology      S8
## 129  1_pre 0.4000       Q3 Biology      S8
## 130  1_pre 0.6667       Q4 Biology      S8
## 131  1_pre 1.0000       Q5 Biology      S8
## 132  1_pre 0.3333       Q6 Biology      S8
## 133  1_pre 0.0000       Q7 Biology      S8
## 134  1_pre 1.0000       Q8  Coding      S8
## 135  1_pre 1.0000       Q9  Coding      S8
## 136  1_pre 0.0000      Q10  Coding      S8
## 137  1_pre 0.6667      Q11  Coding      S8
## 138  1_pre 0.7500      Q12  Coding      S8
## 139  1_pre 0.0000      Q13  Coding      S8
## 140  1_pre 1.0000      Q14  Coding      S8
## 141  1_pre 1.0000      Q15 ProfDev      S8
## 142  1_pre 1.0000      Q16 ProfDev      S8
## 143  1_pre 1.0000      Q17 ProfDev      S8
## 144  1_pre 0.7500      Q18 ProfDev      S8
## 145  1_pre 1.0000       Q1 Biology      S9
## 146  1_pre 0.5000       Q2 Biology      S9
## 147  1_pre 0.8000       Q3 Biology      S9
## 148  1_pre 0.3333       Q4 Biology      S9
## 149  1_pre 1.0000       Q5 Biology      S9
## 150  1_pre 0.6667       Q6 Biology      S9
## 151  1_pre 0.0000       Q7 Biology      S9
## 152  1_pre 1.0000       Q8  Coding      S9
## 153  1_pre 0.5000       Q9  Coding      S9
## 154  1_pre 0.0000      Q10  Coding      S9
## 155  1_pre 1.0000      Q11  Coding      S9
## 156  1_pre 0.2500      Q12  Coding      S9
## 157  1_pre 0.0000      Q13  Coding      S9
## 158  1_pre 1.0000      Q14  Coding      S9
## 159  1_pre 1.0000      Q15 ProfDev      S9
## 160  1_pre 1.0000      Q16 ProfDev      S9
## 161  1_pre 1.0000      Q17 ProfDev      S9
```

```
## 162  1_pre 0.5000      Q18 ProfDev      S9
## 163  1_pre 0.5000       Q1 Biology     S10
## 164  1_pre 0.0000       Q2 Biology     S10
## 165  1_pre 0.8000       Q3 Biology     S10
## 166  1_pre 0.3333       Q4 Biology     S10
## 167  1_pre 0.5000       Q5 Biology     S10
## 168  1_pre 0.3333       Q6 Biology     S10
## 169  1_pre 0.0000       Q7 Biology     S10
## 170  1_pre 0.6667       Q8  Coding     S10
## 171  1_pre 1.0000       Q9  Coding     S10
## 172  1_pre 0.0000      Q10  Coding     S10
## 173  1_pre 0.6667      Q11  Coding     S10
## 174  1_pre 0.0000      Q12  Coding     S10
## 175  1_pre 1.0000      Q13  Coding     S10
## 176  1_pre 0.0000      Q14  Coding     S10
## 177  1_pre 0.4000      Q15 ProfDev     S10
## 178  1_pre 0.8333      Q16 ProfDev     S10
## 179  1_pre 0.5000      Q17 ProfDev     S10
## 180  1_pre 1.0000      Q18 ProfDev     S10
## 181  1_pre 1.0000       Q1 Biology     S11
## 182  1_pre 1.0000       Q2 Biology     S11
## 183  1_pre 1.0000       Q3 Biology     S11
## 184  1_pre 1.0000       Q4 Biology     S11
## 185  1_pre 0.1667       Q5 Biology     S11
## 186  1_pre 1.0000       Q6 Biology     S11
## 187  1_pre 1.0000       Q7 Biology     S11
## 188  1_pre 1.0000       Q8  Coding     S11
## 189  1_pre 1.0000       Q9  Coding     S11
## 190  1_pre 0.0000      Q10  Coding     S11
## 191  1_pre 1.0000      Q11  Coding     S11
## 192  1_pre 0.5000      Q12  Coding     S11
## 193  1_pre 1.0000      Q13  Coding     S11
## 194  1_pre 0.0000      Q14  Coding     S11
## 195  1_pre 1.0000      Q15 ProfDev     S11
## 196  1_pre 1.0000      Q16 ProfDev     S11
## 197  1_pre 1.0000      Q17 ProfDev     S11
## 198  1_pre 0.7500      Q18 ProfDev     S11
## 199  1_pre 0.2500       Q1 Biology     S12
## 200  1_pre 0.0000       Q2 Biology     S12
## 201  1_pre 0.4000       Q3 Biology     S12
## 202  1_pre 0.6667       Q4 Biology     S12
## 203  1_pre 0.5000       Q5 Biology     S12
## 204  1_pre 0.6667       Q6 Biology     S12
## 205  1_pre 0.0000       Q7 Biology     S12
## 206  1_pre 0.6667       Q8  Coding     S12
## 207  1_pre 0.0000       Q9  Coding     S12
## 208  1_pre 0.0000      Q10  Coding     S12
## 209  1_pre 0.0000      Q11  Coding     S12
## 210  1_pre 0.5000      Q12  Coding     S12
## 211  1_pre 1.0000      Q13  Coding     S12
## 212  1_pre 0.0000      Q14  Coding     S12
## 213  1_pre 1.0000      Q15 ProfDev     S12
## 214  1_pre 1.0000      Q16 ProfDev     S12
## 215  1_pre 1.0000      Q17 ProfDev     S12
```

```
## 216  1_pre 0.7500      Q18 ProfDev     S12
## 217  1_pre 0.5000       Q1 Biology     S13
## 218  1_pre 0.0000       Q2 Biology     S13
## 219  1_pre 1.0000       Q3 Biology     S13
## 220  1_pre 1.0000       Q4 Biology     S13
## 221  1_pre 1.0000       Q5 Biology     S13
## 222  1_pre 0.6667       Q6 Biology     S13
## 223  1_pre 0.0000       Q7 Biology     S13
## 224  1_pre 1.0000       Q8  Coding     S13
## 225  1_pre 1.0000       Q9  Coding     S13
## 226  1_pre 0.0000      Q10  Coding     S13
## 227  1_pre 1.0000      Q11  Coding     S13
## 228  1_pre 0.2500      Q12  Coding     S13
## 229  1_pre 0.0000      Q13  Coding     S13
## 230  1_pre 1.0000      Q14  Coding     S13
## 231  1_pre 0.2000      Q15 ProfDev     S13
## 232  1_pre 1.0000      Q16 ProfDev     S13
## 233  1_pre 1.0000      Q17 ProfDev     S13
## 234  1_pre 1.0000      Q18 ProfDev     S13
## 235 2_post 0.5000       Q1 Biology      S1
## 236 2_post 0.5000       Q2 Biology      S1
## 237 2_post 1.0000       Q3 Biology      S1
## 238 2_post 0.6667       Q4 Biology      S1
## 239 2_post 1.0000       Q5 Biology      S1
## 240 2_post 1.0000       Q6 Biology      S1
## 241 2_post 1.0000       Q7 Biology      S1
## 242 2_post 0.6667       Q8  Coding      S1
## 243 2_post 1.0000       Q9  Coding      S1
## 244 2_post 1.0000      Q10  Coding      S1
## 245 2_post 1.0000      Q11  Coding      S1
## 246 2_post 0.5000      Q12  Coding      S1
## 247 2_post 1.0000      Q13  Coding      S1
## 248 2_post 1.0000      Q14  Coding      S1
## 249 2_post 1.0000      Q15 ProfDev      S1
## 250 2_post 1.0000      Q16 ProfDev      S1
## 251 2_post 1.0000      Q17 ProfDev      S1
## 252 2_post 1.0000      Q18 ProfDev      S1
## 253 2_post 0.7500       Q1 Biology      S2
## 254 2_post 1.0000       Q2 Biology      S2
## 255 2_post 0.8000       Q3 Biology      S2
## 256 2_post 0.3333       Q4 Biology      S2
## 257 2_post 0.6667       Q5 Biology      S2
## 258 2_post 0.6667       Q6 Biology      S2
## 259 2_post 1.0000       Q7 Biology      S2
## 260 2_post 1.0000       Q8  Coding      S2
## 261 2_post 0.5000       Q9  Coding      S2
## 262 2_post 1.0000      Q10  Coding      S2
## 263 2_post 0.0000      Q11  Coding      S2
## 264 2_post 0.5000      Q12  Coding      S2
## 265 2_post 1.0000      Q13  Coding      S2
## 266 2_post 0.0000      Q14  Coding      S2
## 267 2_post 0.2000      Q15 ProfDev      S2
## 268 2_post 1.0000      Q16 ProfDev      S2
## 269 2_post 1.0000      Q17 ProfDev      S2
```

```
## 270 2_post 0.7500      Q18 ProfDev      S2
## 271 2_post 1.0000       Q1 Biology      S3
## 272 2_post 1.0000       Q2 Biology      S3
## 273 2_post 1.0000       Q3 Biology      S3
## 274 2_post 1.0000       Q4 Biology      S3
## 275 2_post 1.0000       Q5 Biology      S3
## 276 2_post 1.0000       Q6 Biology      S3
## 277 2_post 1.0000       Q7 Biology      S3
## 278 2_post 0.3333       Q8  Coding      S3
## 279 2_post 1.0000       Q9  Coding      S3
## 280 2_post 1.0000      Q10  Coding      S3
## 281 2_post 1.0000      Q11  Coding      S3
## 282 2_post 1.0000      Q12  Coding      S3
## 283 2_post 1.0000      Q13  Coding      S3
## 284 2_post 1.0000      Q14  Coding      S3
## 285 2_post 1.0000      Q15 ProfDev      S3
## 286 2_post 1.0000      Q16 ProfDev      S3
## 287 2_post 1.0000      Q17 ProfDev      S3
## 288 2_post 1.0000      Q18 ProfDev      S3
## 289 2_post 1.0000       Q1 Biology      S4
## 290 2_post 1.0000       Q2 Biology      S4
## 291 2_post 1.0000       Q3 Biology      S4
## 292 2_post 0.6667       Q4 Biology      S4
## 293 2_post 1.0000       Q5 Biology      S4
## 294 2_post 1.0000       Q6 Biology      S4
## 295 2_post 1.0000       Q7 Biology      S4
## 296 2_post 1.0000       Q8  Coding      S4
## 297 2_post 0.5000       Q9  Coding      S4
## 298 2_post 1.0000      Q10  Coding      S4
## 299 2_post 0.3333      Q11  Coding      S4
## 300 2_post 0.7500      Q12  Coding      S4
## 301 2_post 1.0000      Q13  Coding      S4
## 302 2_post 1.0000      Q14  Coding      S4
## 303 2_post 1.0000      Q15 ProfDev      S4
## 304 2_post 1.0000      Q16 ProfDev      S4
## 305 2_post 1.0000      Q17 ProfDev      S4
## 306 2_post 0.7500      Q18 ProfDev      S4
## 307 2_post 0.7500       Q1 Biology      S5
## 308 2_post 1.0000       Q2 Biology      S5
## 309 2_post 0.8000       Q3 Biology      S5
## 310 2_post 0.3333       Q4 Biology      S5
## 311 2_post 1.0000       Q5 Biology      S5
## 312 2_post 0.6667       Q6 Biology      S5
## 313 2_post 1.0000       Q7 Biology      S5
## 314 2_post 0.3333       Q8  Coding      S5
## 315 2_post 0.5000       Q9  Coding      S5
## 316 2_post 1.0000      Q10  Coding      S5
## 317 2_post 1.0000      Q11  Coding      S5
## 318 2_post 0.5000      Q12  Coding      S5
## 319 2_post 1.0000      Q13  Coding      S5
## 320 2_post 1.0000      Q14  Coding      S5
## 321 2_post 0.4000      Q15 ProfDev      S5
## 322 2_post 1.0000      Q16 ProfDev      S5
## 323 2_post 1.0000      Q17 ProfDev      S5
```

```
## 324 2_post 0.7500      Q18 ProfDev      S5
## 325 2_post 0.5000       Q1 Biology      S6
## 326 2_post 1.0000       Q2 Biology      S6
## 327 2_post 1.0000       Q3 Biology      S6
## 328 2_post 0.6667       Q4 Biology      S6
## 329 2_post 0.0000       Q5 Biology      S6
## 330 2_post 0.6667       Q6 Biology      S6
## 331 2_post 0.0000       Q7 Biology      S6
## 332 2_post 0.6667       Q8  Coding      S6
## 333 2_post 0.5000       Q9  Coding      S6
## 334 2_post 0.0000      Q10  Coding      S6
## 335 2_post 0.3333      Q11  Coding      S6
## 336 2_post 0.2500      Q12  Coding      S6
## 337 2_post 0.0000      Q13  Coding      S6
## 338 2_post 0.0000      Q14  Coding      S6
## 339 2_post 0.2000      Q15 ProfDev      S6
## 340 2_post 1.0000      Q16 ProfDev      S6
## 341 2_post 1.0000      Q17 ProfDev      S6
## 342 2_post 0.7500      Q18 ProfDev      S6
## 343 2_post 1.0000       Q1 Biology      S7
## 344 2_post 1.0000       Q2 Biology      S7
## 345 2_post 1.0000       Q3 Biology      S7
## 346 2_post 1.0000       Q4 Biology      S7
## 347 2_post 1.0000       Q5 Biology      S7
## 348 2_post 1.0000       Q6 Biology      S7
## 349 2_post 1.0000       Q7 Biology      S7
## 350 2_post 0.0000       Q8  Coding      S7
## 351 2_post 1.0000       Q9  Coding      S7
## 352 2_post 1.0000      Q10  Coding      S7
## 353 2_post 1.0000      Q11  Coding      S7
## 354 2_post 1.0000      Q12  Coding      S7
## 355 2_post 1.0000      Q13  Coding      S7
## 356 2_post 1.0000      Q14  Coding      S7
## 357 2_post 0.6000      Q15 ProfDev      S7
## 358 2_post 1.0000      Q16 ProfDev      S7
## 359 2_post 1.0000      Q17 ProfDev      S7
## 360 2_post 1.0000      Q18 ProfDev      S7
## 361 2_post 1.0000       Q1 Biology      S8
## 362 2_post 1.0000       Q2 Biology      S8
## 363 2_post 0.8000       Q3 Biology      S8
## 364 2_post 0.6667       Q4 Biology      S8
## 365 2_post 0.8333       Q5 Biology      S8
## 366 2_post 1.0000       Q6 Biology      S8
## 367 2_post 1.0000       Q7 Biology      S8
## 368 2_post 0.6667       Q8  Coding      S8
## 369 2_post 0.5000       Q9  Coding      S8
## 370 2_post 0.0000      Q10  Coding      S8
## 371 2_post 1.0000      Q11  Coding      S8
## 372 2_post 1.0000      Q12  Coding      S8
## 373 2_post 1.0000      Q13  Coding      S8
## 374 2_post 1.0000      Q14  Coding      S8
## 375 2_post 1.0000      Q15 ProfDev      S8
## 376 2_post 1.0000      Q16 ProfDev      S8
## 377 2_post 1.0000      Q17 ProfDev      S8
```

```
## 378 2_post 0.7500      Q18 ProfDev      S8
## 379 2_post 1.0000       Q1 Biology      S9
## 380 2_post 1.0000       Q2 Biology      S9
## 381 2_post 1.0000       Q3 Biology      S9
## 382 2_post 0.6667       Q4 Biology      S9
## 383 2_post 1.0000       Q5 Biology      S9
## 384 2_post 1.0000       Q6 Biology      S9
## 385 2_post 1.0000       Q7 Biology      S9
## 386 2_post 1.0000       Q8  Coding      S9
## 387 2_post 1.0000       Q9  Coding      S9
## 388 2_post 1.0000      Q10  Coding      S9
## 389 2_post 1.0000      Q11  Coding      S9
## 390 2_post 1.0000      Q12  Coding      S9
## 391 2_post 1.0000      Q13  Coding      S9
## 392 2_post 1.0000      Q14  Coding      S9
## 393 2_post 1.0000      Q15 ProfDev      S9
## 394 2_post 1.0000      Q16 ProfDev      S9
## 395 2_post 1.0000      Q17 ProfDev      S9
## 396 2_post 0.7500      Q18 ProfDev      S9
## 397 2_post 0.7500       Q1 Biology     S10
## 398 2_post 1.0000       Q2 Biology     S10
## 399 2_post 1.0000       Q3 Biology     S10
## 400 2_post 0.0000       Q4 Biology     S10
## 401 2_post 0.3333       Q5 Biology     S10
## 402 2_post 1.0000       Q6 Biology     S10
## 403 2_post 0.0000       Q7 Biology     S10
## 404 2_post 1.0000       Q8  Coding     S10
## 405 2_post 1.0000       Q9  Coding     S10
## 406 2_post 0.0000      Q10  Coding     S10
## 407 2_post 1.0000      Q11  Coding     S10
## 408 2_post 0.5000      Q12  Coding     S10
## 409 2_post 0.0000      Q13  Coding     S10
## 410 2_post 0.0000      Q14  Coding     S10
## 411 2_post 1.0000      Q15 ProfDev     S10
## 412 2_post 0.8333      Q16 ProfDev     S10
## 413 2_post 1.0000      Q17 ProfDev     S10
## 414 2_post 0.7500      Q18 ProfDev     S10
## 415 2_post 1.0000       Q1 Biology     S11
## 416 2_post 1.0000       Q2 Biology     S11
## 417 2_post 1.0000       Q3 Biology     S11
## 418 2_post 0.3333       Q4 Biology     S11
## 419 2_post 1.0000       Q5 Biology     S11
## 420 2_post 1.0000       Q6 Biology     S11
## 421 2_post 1.0000       Q7 Biology     S11
## 422 2_post 1.0000       Q8  Coding     S11
## 423 2_post 0.5000       Q9  Coding     S11
## 424 2_post 1.0000      Q10  Coding     S11
## 425 2_post 0.6667      Q11  Coding     S11
## 426 2_post 0.5000      Q12  Coding     S11
## 427 2_post 1.0000      Q13  Coding     S11
## 428 2_post 0.0000      Q14  Coding     S11
## 429 2_post 1.0000      Q15 ProfDev     S11
## 430 2_post 1.0000      Q16 ProfDev     S11
## 431 2_post 1.0000      Q17 ProfDev     S11
```

```
## 432 2_post 1.0000      Q18 ProfDev     S11
## 433 2_post 0.5000       Q1 Biology     S12
## 434 2_post 0.0000       Q2 Biology     S12
## 435 2_post 0.6000       Q3 Biology     S12
## 436 2_post 0.6667       Q4 Biology     S12
## 437 2_post 0.1667       Q5 Biology     S12
## 438 2_post 0.3333       Q6 Biology     S12
## 439 2_post 1.0000       Q7 Biology     S12
## 440 2_post 1.0000       Q8  Coding     S12
## 441 2_post 1.0000       Q9  Coding     S12
## 442 2_post 1.0000      Q10  Coding     S12
## 443 2_post 0.6667      Q11  Coding     S12
## 444 2_post 0.5000      Q12  Coding     S12
## 445 2_post 0.0000      Q13  Coding     S12
## 446 2_post 0.0000      Q14  Coding     S12
## 447 2_post 0.6000      Q15 ProfDev     S12
## 448 2_post 1.0000      Q16 ProfDev     S12
## 449 2_post 1.0000      Q17 ProfDev     S12
## 450 2_post 0.5000      Q18 ProfDev     S12
## 451 2_post 0.7500       Q1 Biology     S14
## 452 2_post 0.0000       Q2 Biology     S14
## 453 2_post 1.0000       Q3 Biology     S14
## 454 2_post 0.0000       Q4 Biology     S14
## 455 2_post 1.0000       Q5 Biology     S14
## 456 2_post 0.6667       Q6 Biology     S14
## 457 2_post 1.0000       Q7 Biology     S14
## 458 2_post 0.3333       Q8  Coding     S14
## 459 2_post 0.5000       Q9  Coding     S14
## 460 2_post 1.0000      Q10  Coding     S14
## 461 2_post 0.6667      Q11  Coding     S14
## 462 2_post 0.5000      Q12  Coding     S14
## 463 2_post 0.0000      Q13  Coding     S14
## 464 2_post 1.0000      Q14  Coding     S14
## 465 2_post 0.6000      Q15 ProfDev     S14
## 466 2_post 1.0000      Q16 ProfDev     S14
## 467 2_post 1.0000      Q17 ProfDev     S14
## 468 2_post 0.7500      Q18 ProfDev     S14
```

```
# Filter the data by topic using dplyr
# Biology questions
bio_pre_stats <- df_questions_pre %>%
  filter(topic == "Biology") %>%
  summary(bio_pre_stats)
bio_pre_stats
```

```
##      score         question           topic             student
##  Min.   :0.000   Length:91          Length:91          Length:91
##  1st Qu.:0.333   Class :character   Class :character   Class :character
##  Median :0.667   Mode  :character   Mode  :character   Mode  :character
##  Mean   :0.627
##  3rd Qu.:1.000
##  Max.   :1.000
##   assessment
##  Length:91
```

```
##  Class :character
##  Mode  :character
##
##
##
```

```
bio_post_stats <- df_questions_post %>%
  filter(topic == "Biology") %>%
  summary(bio_pre_stats)
bio_post_stats
```

```
##      score         question            topic             student
##  Min.   :0.000   Length:91          Length:91          Length:91
##  1st Qu.:0.667   Class :character   Class :character   Class :character
##  Median :1.000   Mode  :character   Mode  :character   Mode  :character
##  Mean   :0.791
##  3rd Qu.:1.000
##  Max.   :1.000
##   assessment
##  Length:91
##  Class :character
##  Mode  :character
##
##
##
```

```
# Coding questions
coding_pre_stats <- df_questions_pre %>%
  filter(topic == "Coding") %>%
  summary(coding_pre_stats)
coding_pre_stats
```

```
##      score         question            topic             student
##  Min.   :0.000   Length:91          Length:91          Length:91
##  1st Qu.:0.000   Class :character   Class :character   Class :character
##  Median :0.667   Mode  :character   Mode  :character   Mode  :character
##  Mean   :0.589
##  3rd Qu.:1.000
##  Max.   :1.000
##   assessment
##  Length:91
##  Class :character
##  Mode  :character
##
##
##
```

```
coding_post_stats <- df_questions_post %>%
  filter(topic == "Coding") %>%
  summary(coding_post_stats)
coding_post_stats
```

```
##      score       question            topic             student
##  Min.   :0.0   Length:91          Length:91          Length:91
##  1st Qu.:0.5   Class :character   Class :character   Class :character
##  Median :1.0   Mode  :character   Mode  :character   Mode  :character
##  Mean   :0.7
##  3rd Qu.:1.0
##  Max.   :1.0
##   assessment
##  Length:91
##  Class :character
##  Mode  :character
##
##
##
```

```
# Professional development (pd) questions
pd_pre_stats <- df_questions_pre %>%
  filter(topic == "ProfDev") %>%
  summary(pd_pre_stats)
pd_pre_stats
```

```
##      score         question            topic             student
##  Min.   :0.000   Length:52          Length:52          Length:52
##  1st Qu.:0.750   Class :character   Class :character   Class :character
##  Median :1.000   Mode  :character   Mode  :character   Mode  :character
##  Mean   :0.841
##  3rd Qu.:1.000
##  Max.   :1.000
##   assessment
##  Length:52
##  Class :character
##  Mode  :character
##
##
##
```

```
pd_post_stats <- df_questions_post %>%
  filter(topic == "ProfDev") %>%
  summary(pd_post_stats)
pd_post_stats
```

```
##      score         question            topic             student
##  Min.   :0.200   Length:52          Length:52          Length:52
##  1st Qu.:0.750   Class :character   Class :character   Class :character
##  Median :1.000   Mode  :character   Mode  :character   Mode  :character
##  Mean   :0.883
##  3rd Qu.:1.000
##  Max.   :1.000
##   assessment
##  Length:52
##  Class :character
##  Mode  :character
##
```

```
##
##
```

```
# Create a boxplot of scores by pre and post topics
questions_pre_boxplot <- ggpaired(df_questions_pre, x = "topic", y = "score",
 color = "topic", line.color = "gray", line.size = 0.4, position = "identity",
 palette = "npg",   title = "Student performance by topic before the CURE",
  xlab = "Assessment",
  ylab = "Overall score (%)")

questions_post_boxplot <- ggpaired(df_questions_post, x = "topic", y = "score",
 color = "topic", line.color = "gray", line.size = 0.4, position = "identity",
 palette = "npg",   title = "Student performance by topic after the CURE",
  xlab = "Assessment",
  ylab = "Overall score (%)")


# paired sum plot

questions_all = rbind(questions_pre,questions_post)

questions_all_sum = aggregate(questions_all$Score, by = list(questions_all$Topic, questions_all$Type,qu
colnames(questions_all_sum) = c("Topic","Type","Student","SumScore")
#write.csv(questions_all_sum, file = "SumCorrect_questions.csv")

questions_all_sum$Type <- factor(questions_all_sum$Type , levels=c("prescore", "postscore"))
pattern = c("darkcyan","red3")

sum_by_topic = ggplot(questions_all_sum, aes(x = Type, y = SumScore)) +
  geom_boxplot(aes(fill = Topic), alpha = .2, color = c("darkcyan","red3","darkcyan","red3","darkcyan",
  scale_x_discrete(labels=c("prescore" = "pre", "postscore" = "post"), name = element_blank()) +
  geom_line(aes(group = Student), color = "gray", size = 0.4, position = "identity") +
  geom_point(size = 1) +
  facet_wrap(~ Topic) +
  theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank())
```

```
## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use `linewidth` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

```
ggsave(filename = "C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/sum_score_by
```

```
## Saving 6.5 x 4.5 in image
```

```
# cohen's score and ttest p-value by topic
score_post = questions_all_sum$SumScore[questions_all_sum$Type == "postscore" & questions_all_sum$Topic
score_pre = questions_all_sum$SumScore[questions_all_sum$Type == "prescore" & questions_all_sum$Topic ==
effsize::cohen.d(score_post, score_pre)
```

```
##
```

```
## Cohen's d
##
## d estimate: 0.868 (large)
## 95 percent confidence interval:
##   lower   upper
## 0.02118 1.71475
```

```
t.test(score_post, score_pre, paired = TRUE, alternative = "two.sided")
```

```
##
##  Paired t-test
##
## data:  score_post and score_pre
## t = 3.5, df = 12, p-value = 0.004
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  0.433 1.870
## sample estimates:
## mean difference
##           1.151
```

```
score_post = questions_all_sum$SumScore[questions_all_sum$Type == "postscore" & questions_all_sum$Topic
score_pre = questions_all_sum$SumScore[questions_all_sum$Type == "prescore" & questions_all_sum$Topic ==
effsize::cohen.d(score_post, score_pre)
```

```
##
## Cohen's d
##
## d estimate: 0.5955 (medium)
## 95 percent confidence interval:
##   lower   upper
## -0.2318  1.4228
```

```
t.test(score_post, score_pre, paired = TRUE, alternative = "two.sided")
```

```
##
##  Paired t-test
##
## data:  score_post and score_pre
## t = 2.5, df = 12, p-value = 0.03
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  0.1008 1.4504
## sample estimates:
## mean difference
##          0.7756
```

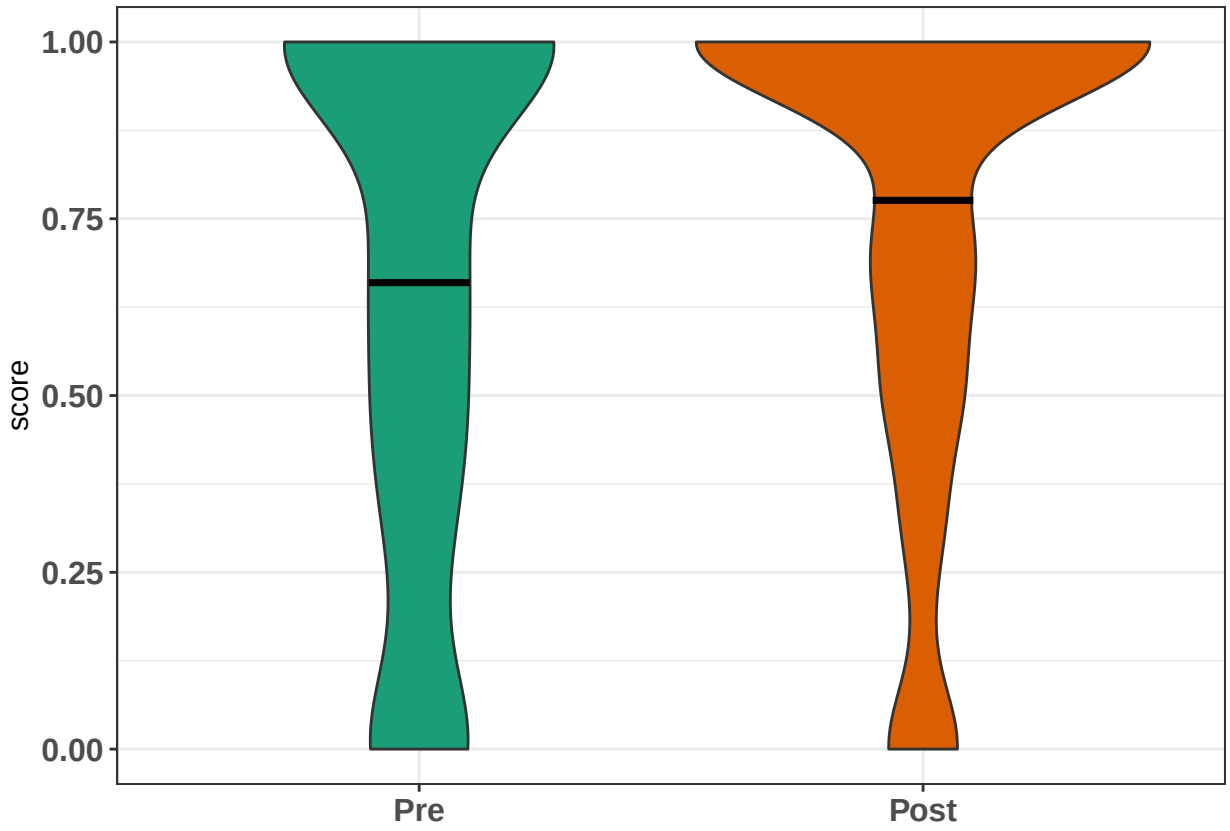
```
score_post = questions_all_sum$SumScore[questions_all_sum$Type == "postscore" & questions_all_sum$Topic
score_pre = questions_all_sum$SumScore[questions_all_sum$Type == "prescore" & questions_all_sum$Topic ==
effsize::cohen.d(score_post, score_pre)
```

```
##
## Cohen's d
##
## d estimate: 0.4464 (small)
## 95 percent confidence interval:
##   lower   upper
## -0.3732  1.2659
```

```
t.test(score_post, score_pre, paired = TRUE, alternative = "two.sided")
```

```
##
##  Paired t-test
##
## data:  score_post and score_pre
## t = 1.6, df = 12, p-value = 0.1
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  -0.0545  0.3930
## sample estimates:
## mean difference
##          0.1692
```

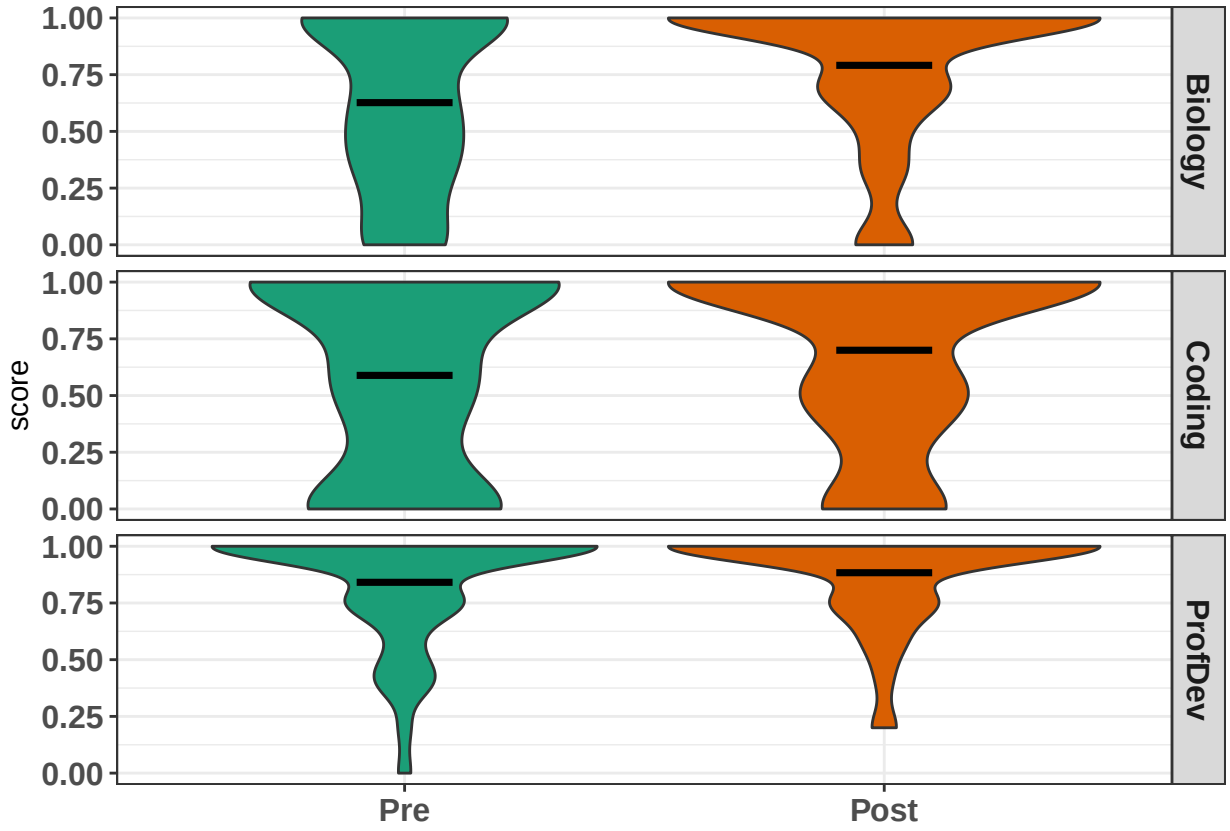
```
# Question performance scores distribution overall
v <- ggplot(question_data, aes(x = group, y = score, fill = group, fontface = "bold")) +
  scale_fill_brewer(palette="Dark2") +
  geom_violin(trim=TRUE) +
  stat_summary(fun = "mean",
               geom = "crossbar",
               width = 0.2,
               color = "black") +                                                    # Chan
  theme(strip.text.x = element_text(size = 12),
        legend.position = "none",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12)) +
  scale_x_discrete(labels=c("1_pre" = "Pre", "2_post" = "Post"), name = element_blank())
v
```




```
# Question performance scores by topic
pv <- v + facet_grid(rows = vars(topic)) +
  theme(strip.text.y = element_text(face= "bold", size = 12)) +
  scale_x_discrete(labels=c("1_pre" = "Pre", "2_post" = "Post"), name = element_blank())
```

```
## Scale for x is already present.
## Adding another scale for x, which will replace the existing scale.
```

```
#   labs(title = "Plot of individual question scores by topic")
pv
```




```
ggsave(filename = "violin_by_topic.pdf", plot = pv)
```

```
## Saving 6.5 x 4.5 in image
```

```
# Filter the data using dplyr
bio_pre <- df_questions_pre %>%
  filter(topic == "Biology")
bio_pre
```

```
##     score question   topic student assessment
## 1  0.5000       Q1 Biology      S1      1_pre
## 2  0.0000       Q2 Biology      S1      1_pre
## 3  1.0000       Q3 Biology      S1      1_pre
## 4  1.0000       Q4 Biology      S1      1_pre
## 5  1.0000       Q5 Biology      S1      1_pre
## 6  1.0000       Q6 Biology      S1      1_pre
## 7  1.0000       Q7 Biology      S1      1_pre
## 8  1.0000       Q1 Biology      S2      1_pre
## 9  0.0000       Q2 Biology      S2      1_pre
## 10 0.4000       Q3 Biology      S2      1_pre
## 11 0.3333       Q4 Biology      S2      1_pre
## 12 0.5000       Q5 Biology      S2      1_pre
## 13 0.6667       Q6 Biology      S2      1_pre
## 14 1.0000       Q7 Biology      S2      1_pre
## 15 0.2500       Q1 Biology      S3      1_pre
```

```
## 16 0.0000       Q2 Biology      S3      1_pre
## 17 0.6000       Q3 Biology      S3      1_pre
## 18 0.0000       Q4 Biology      S3      1_pre
## 19 0.1667       Q5 Biology      S3      1_pre
## 20 0.6667       Q6 Biology      S3      1_pre
## 21 1.0000       Q7 Biology      S3      1_pre
## 22 1.0000       Q1 Biology      S4      1_pre
## 23 1.0000       Q2 Biology      S4      1_pre
## 24 0.8000       Q3 Biology      S4      1_pre
## 25 1.0000       Q4 Biology      S4      1_pre
## 26 0.1667       Q5 Biology      S4      1_pre
## 27 1.0000       Q6 Biology      S4      1_pre
## 28 1.0000       Q7 Biology      S4      1_pre
## 29 0.7500       Q1 Biology      S5      1_pre
## 30 1.0000       Q2 Biology      S5      1_pre
## 31 0.6000       Q3 Biology      S5      1_pre
## 32 0.3333       Q4 Biology      S5      1_pre
## 33 0.5000       Q5 Biology      S5      1_pre
## 34 0.6667       Q6 Biology      S5      1_pre
## 35 1.0000       Q7 Biology      S5      1_pre
## 36 0.2500       Q1 Biology      S6      1_pre
## 37 0.0000       Q2 Biology      S6      1_pre
## 38 0.4000       Q3 Biology      S6      1_pre
## 39 0.6667       Q4 Biology      S6      1_pre
## 40 1.0000       Q5 Biology      S6      1_pre
## 41 0.3333       Q6 Biology      S6      1_pre
## 42 1.0000       Q7 Biology      S6      1_pre
## 43 1.0000       Q1 Biology      S7      1_pre
## 44 0.5000       Q2 Biology      S7      1_pre
## 45 1.0000       Q3 Biology      S7      1_pre
## 46 1.0000       Q4 Biology      S7      1_pre
## 47 1.0000       Q5 Biology      S7      1_pre
## 48 1.0000       Q6 Biology      S7      1_pre
## 49 1.0000       Q7 Biology      S7      1_pre
## 50 1.0000       Q1 Biology      S8      1_pre
## 51 1.0000       Q2 Biology      S8      1_pre
## 52 0.4000       Q3 Biology      S8      1_pre
## 53 0.6667       Q4 Biology      S8      1_pre
## 54 1.0000       Q5 Biology      S8      1_pre
## 55 0.3333       Q6 Biology      S8      1_pre
## 56 0.0000       Q7 Biology      S8      1_pre
## 57 1.0000       Q1 Biology      S9      1_pre
## 58 0.5000       Q2 Biology      S9      1_pre
## 59 0.8000       Q3 Biology      S9      1_pre
## 60 0.3333       Q4 Biology      S9      1_pre
## 61 1.0000       Q5 Biology      S9      1_pre
## 62 0.6667       Q6 Biology      S9      1_pre
## 63 0.0000       Q7 Biology      S9      1_pre
## 64 0.5000       Q1 Biology     S10      1_pre
## 65 0.0000       Q2 Biology     S10      1_pre
## 66 0.8000       Q3 Biology     S10      1_pre
## 67 0.3333       Q4 Biology     S10      1_pre
## 68 0.5000       Q5 Biology     S10      1_pre
## 69 0.3333       Q6 Biology     S10      1_pre
```

```
## 70 0.0000       Q7 Biology     S10      1_pre
## 71 1.0000       Q1 Biology     S11      1_pre
## 72 1.0000       Q2 Biology     S11      1_pre
## 73 1.0000       Q3 Biology     S11      1_pre
## 74 1.0000       Q4 Biology     S11      1_pre
## 75 0.1667       Q5 Biology     S11      1_pre
## 76 1.0000       Q6 Biology     S11      1_pre
## 77 1.0000       Q7 Biology     S11      1_pre
## 78 0.2500       Q1 Biology     S12      1_pre
## 79 0.0000       Q2 Biology     S12      1_pre
## 80 0.4000       Q3 Biology     S12      1_pre
## 81 0.6667       Q4 Biology     S12      1_pre
## 82 0.5000       Q5 Biology     S12      1_pre
## 83 0.6667       Q6 Biology     S12      1_pre
## 84 0.0000       Q7 Biology     S12      1_pre
## 85 0.5000       Q1 Biology     S13      1_pre
## 86 0.0000       Q2 Biology     S13      1_pre
## 87 1.0000       Q3 Biology     S13      1_pre
## 88 1.0000       Q4 Biology     S13      1_pre
## 89 1.0000       Q5 Biology     S13      1_pre
## 90 0.6667       Q6 Biology     S13      1_pre
## 91 0.0000       Q7 Biology     S13      1_pre
```

```
bio_post <- df_questions_post %>%
  filter(topic == "Biology")
bio_post
```

```
##     score question   topic student assessment
## 1  0.5000       Q1 Biology      S1     2_post
## 2  0.5000       Q2 Biology      S1     2_post
## 3  1.0000       Q3 Biology      S1     2_post
## 4  0.6667       Q4 Biology      S1     2_post
## 5  1.0000       Q5 Biology      S1     2_post
## 6  1.0000       Q6 Biology      S1     2_post
## 7  1.0000       Q7 Biology      S1     2_post
## 8  0.7500       Q1 Biology      S2     2_post
## 9  1.0000       Q2 Biology      S2     2_post
## 10 0.8000       Q3 Biology      S2     2_post
## 11 0.3333       Q4 Biology      S2     2_post
## 12 0.6667       Q5 Biology      S2     2_post
## 13 0.6667       Q6 Biology      S2     2_post
## 14 1.0000       Q7 Biology      S2     2_post
## 15 1.0000       Q1 Biology      S3     2_post
## 16 1.0000       Q2 Biology      S3     2_post
## 17 1.0000       Q3 Biology      S3     2_post
## 18 1.0000       Q4 Biology      S3     2_post
## 19 1.0000       Q5 Biology      S3     2_post
## 20 1.0000       Q6 Biology      S3     2_post
## 21 1.0000       Q7 Biology      S3     2_post
## 22 1.0000       Q1 Biology      S4     2_post
## 23 1.0000       Q2 Biology      S4     2_post
## 24 1.0000       Q3 Biology      S4     2_post
## 25 0.6667       Q4 Biology      S4     2_post
## 26 1.0000       Q5 Biology      S4     2_post
```

```
## 27 1.0000       Q6 Biology      S4     2_post
## 28 1.0000       Q7 Biology      S4     2_post
## 29 0.7500       Q1 Biology      S5     2_post
## 30 1.0000       Q2 Biology      S5     2_post
## 31 0.8000       Q3 Biology      S5     2_post
## 32 0.3333       Q4 Biology      S5     2_post
## 33 1.0000       Q5 Biology      S5     2_post
## 34 0.6667       Q6 Biology      S5     2_post
## 35 1.0000       Q7 Biology      S5     2_post
## 36 0.5000       Q1 Biology      S6     2_post
## 37 1.0000       Q2 Biology      S6     2_post
## 38 1.0000       Q3 Biology      S6     2_post
## 39 0.6667       Q4 Biology      S6     2_post
## 40 0.0000       Q5 Biology      S6     2_post
## 41 0.6667       Q6 Biology      S6     2_post
## 42 0.0000       Q7 Biology      S6     2_post
## 43 1.0000       Q1 Biology      S7     2_post
## 44 1.0000       Q2 Biology      S7     2_post
## 45 1.0000       Q3 Biology      S7     2_post
## 46 1.0000       Q4 Biology      S7     2_post
## 47 1.0000       Q5 Biology      S7     2_post
## 48 1.0000       Q6 Biology      S7     2_post
## 49 1.0000       Q7 Biology      S7     2_post
## 50 1.0000       Q1 Biology      S8     2_post
## 51 1.0000       Q2 Biology      S8     2_post
## 52 0.8000       Q3 Biology      S8     2_post
## 53 0.6667       Q4 Biology      S8     2_post
## 54 0.8333       Q5 Biology      S8     2_post
## 55 1.0000       Q6 Biology      S8     2_post
## 56 1.0000       Q7 Biology      S8     2_post
## 57 1.0000       Q1 Biology      S9     2_post
## 58 1.0000       Q2 Biology      S9     2_post
## 59 1.0000       Q3 Biology      S9     2_post
## 60 0.6667       Q4 Biology      S9     2_post
## 61 1.0000       Q5 Biology      S9     2_post
## 62 1.0000       Q6 Biology      S9     2_post
## 63 1.0000       Q7 Biology      S9     2_post
## 64 0.7500       Q1 Biology     S10     2_post
## 65 1.0000       Q2 Biology     S10     2_post
## 66 1.0000       Q3 Biology     S10     2_post
## 67 0.0000       Q4 Biology     S10     2_post
## 68 0.3333       Q5 Biology     S10     2_post
## 69 1.0000       Q6 Biology     S10     2_post
## 70 0.0000       Q7 Biology     S10     2_post
## 71 1.0000       Q1 Biology     S11     2_post
## 72 1.0000       Q2 Biology     S11     2_post
## 73 1.0000       Q3 Biology     S11     2_post
## 74 0.3333       Q4 Biology     S11     2_post
## 75 1.0000       Q5 Biology     S11     2_post
## 76 1.0000       Q6 Biology     S11     2_post
## 77 1.0000       Q7 Biology     S11     2_post
## 78 0.5000       Q1 Biology     S12     2_post
## 79 0.0000       Q2 Biology     S12     2_post
## 80 0.6000       Q3 Biology     S12     2_post
```

```
## 81 0.6667       Q4 Biology     S12     2_post
## 82 0.1667       Q5 Biology     S12     2_post
## 83 0.3333       Q6 Biology     S12     2_post
## 84 1.0000       Q7 Biology     S12     2_post
## 85 0.7500       Q1 Biology     S14     2_post
## 86 0.0000       Q2 Biology     S14     2_post
## 87 1.0000       Q3 Biology     S14     2_post
## 88 0.0000       Q4 Biology     S14     2_post
## 89 1.0000       Q5 Biology     S14     2_post
## 90 0.6667       Q6 Biology     S14     2_post
## 91 1.0000       Q7 Biology     S14     2_post
```

```
coding_pre <- df_questions_pre %>%
  filter(topic == "Coding")
coding_pre
```

```
##     score question  topic student assessment
## 1  0.6667       Q8 Coding      S1      1_pre
## 2  1.0000       Q9 Coding      S1      1_pre
## 3  1.0000      Q10 Coding      S1      1_pre
## 4  0.3333      Q11 Coding      S1      1_pre
## 5  0.7500      Q12 Coding      S1      1_pre
## 6  0.0000      Q13 Coding      S1      1_pre
## 7  1.0000      Q14 Coding      S1      1_pre
## 8  1.0000       Q8 Coding      S2      1_pre
## 9  0.5000       Q9 Coding      S2      1_pre
## 10 0.0000      Q10 Coding      S2      1_pre
## 11 0.6667      Q11 Coding      S2      1_pre
## 12 0.5000      Q12 Coding      S2      1_pre
## 13 1.0000      Q13 Coding      S2      1_pre
## 14 1.0000      Q14 Coding      S2      1_pre
## 15 0.3333       Q8 Coding      S3      1_pre
## 16 1.0000       Q9 Coding      S3      1_pre
## 17 0.0000      Q10 Coding      S3      1_pre
## 18 0.6667      Q11 Coding      S3      1_pre
## 19 0.5000      Q12 Coding      S3      1_pre
## 20 1.0000      Q13 Coding      S3      1_pre
## 21 1.0000      Q14 Coding      S3      1_pre
## 22 1.0000       Q8 Coding      S4      1_pre
## 23 0.5000       Q9 Coding      S4      1_pre
## 24 1.0000      Q10 Coding      S4      1_pre
## 25 1.0000      Q11 Coding      S4      1_pre
## 26 0.0000      Q12 Coding      S4      1_pre
## 27 1.0000      Q13 Coding      S4      1_pre
## 28 0.0000      Q14 Coding      S4      1_pre
## 29 1.0000       Q8 Coding      S5      1_pre
## 30 0.5000       Q9 Coding      S5      1_pre
## 31 0.0000      Q10 Coding      S5      1_pre
## 32 0.6667      Q11 Coding      S5      1_pre
## 33 0.5000      Q12 Coding      S5      1_pre
## 34 1.0000      Q13 Coding      S5      1_pre
## 35 1.0000      Q14 Coding      S5      1_pre
## 36 0.6667       Q8 Coding      S6      1_pre
## 37 0.5000       Q9 Coding      S6      1_pre
```

```
## 38 0.0000      Q10 Coding      S6      1_pre
## 39 0.3333      Q11 Coding      S6      1_pre
## 40 0.2500      Q12 Coding      S6      1_pre
## 41 0.0000      Q13 Coding      S6      1_pre
## 42 0.0000      Q14 Coding      S6      1_pre
## 43 0.3333       Q8 Coding      S7      1_pre
## 44 1.0000       Q9 Coding      S7      1_pre
## 45 1.0000      Q10 Coding      S7      1_pre
## 46 1.0000      Q11 Coding      S7      1_pre
## 47 1.0000      Q12 Coding      S7      1_pre
## 48 1.0000      Q13 Coding      S7      1_pre
## 49 1.0000      Q14 Coding      S7      1_pre
## 50 1.0000       Q8 Coding      S8      1_pre
## 51 1.0000       Q9 Coding      S8      1_pre
## 52 0.0000      Q10 Coding      S8      1_pre
## 53 0.6667      Q11 Coding      S8      1_pre
## 54 0.7500      Q12 Coding      S8      1_pre
## 55 0.0000      Q13 Coding      S8      1_pre
## 56 1.0000      Q14 Coding      S8      1_pre
## 57 1.0000       Q8 Coding      S9      1_pre
## 58 0.5000       Q9 Coding      S9      1_pre
## 59 0.0000      Q10 Coding      S9      1_pre
## 60 1.0000      Q11 Coding      S9      1_pre
## 61 0.2500      Q12 Coding      S9      1_pre
## 62 0.0000      Q13 Coding      S9      1_pre
## 63 1.0000      Q14 Coding      S9      1_pre
## 64 0.6667       Q8 Coding     S10      1_pre
## 65 1.0000       Q9 Coding     S10      1_pre
## 66 0.0000      Q10 Coding     S10      1_pre
## 67 0.6667      Q11 Coding     S10      1_pre
## 68 0.0000      Q12 Coding     S10      1_pre
## 69 1.0000      Q13 Coding     S10      1_pre
## 70 0.0000      Q14 Coding     S10      1_pre
## 71 1.0000       Q8 Coding     S11      1_pre
## 72 1.0000       Q9 Coding     S11      1_pre
## 73 0.0000      Q10 Coding     S11      1_pre
## 74 1.0000      Q11 Coding     S11      1_pre
## 75 0.5000      Q12 Coding     S11      1_pre
## 76 1.0000      Q13 Coding     S11      1_pre
## 77 0.0000      Q14 Coding     S11      1_pre
## 78 0.6667       Q8 Coding     S12      1_pre
## 79 0.0000       Q9 Coding     S12      1_pre
## 80 0.0000      Q10 Coding     S12      1_pre
## 81 0.0000      Q11 Coding     S12      1_pre
## 82 0.5000      Q12 Coding     S12      1_pre
## 83 1.0000      Q13 Coding     S12      1_pre
## 84 0.0000      Q14 Coding     S12      1_pre
## 85 1.0000       Q8 Coding     S13      1_pre
## 86 1.0000       Q9 Coding     S13      1_pre
## 87 0.0000      Q10 Coding     S13      1_pre
## 88 1.0000      Q11 Coding     S13      1_pre
## 89 0.2500      Q12 Coding     S13      1_pre
## 90 0.0000      Q13 Coding     S13      1_pre
## 91 1.0000      Q14 Coding     S13      1_pre
```

```r
coding_post <- df_questions_post %>%
  filter(topic == "Coding")
coding_post
```

```
##     score question  topic student assessment
## 1  0.6667       Q8 Coding      S1     2_post
## 2  1.0000       Q9 Coding      S1     2_post
## 3  1.0000      Q10 Coding      S1     2_post
## 4  1.0000      Q11 Coding      S1     2_post
## 5  0.5000      Q12 Coding      S1     2_post
## 6  1.0000      Q13 Coding      S1     2_post
## 7  1.0000      Q14 Coding      S1     2_post
## 8  1.0000       Q8 Coding      S2     2_post
## 9  0.5000       Q9 Coding      S2     2_post
## 10 1.0000      Q10 Coding      S2     2_post
## 11 0.0000      Q11 Coding      S2     2_post
## 12 0.5000      Q12 Coding      S2     2_post
## 13 1.0000      Q13 Coding      S2     2_post
## 14 0.0000      Q14 Coding      S2     2_post
## 15 0.3333       Q8 Coding      S3     2_post
## 16 1.0000       Q9 Coding      S3     2_post
## 17 1.0000      Q10 Coding      S3     2_post
## 18 1.0000      Q11 Coding      S3     2_post
## 19 1.0000      Q12 Coding      S3     2_post
## 20 1.0000      Q13 Coding      S3     2_post
## 21 1.0000      Q14 Coding      S3     2_post
## 22 1.0000       Q8 Coding      S4     2_post
## 23 0.5000       Q9 Coding      S4     2_post
## 24 1.0000      Q10 Coding      S4     2_post
## 25 0.3333      Q11 Coding      S4     2_post
## 26 0.7500      Q12 Coding      S4     2_post
## 27 1.0000      Q13 Coding      S4     2_post
## 28 1.0000      Q14 Coding      S4     2_post
## 29 0.3333       Q8 Coding      S5     2_post
## 30 0.5000       Q9 Coding      S5     2_post
## 31 1.0000      Q10 Coding      S5     2_post
## 32 1.0000      Q11 Coding      S5     2_post
## 33 0.5000      Q12 Coding      S5     2_post
## 34 1.0000      Q13 Coding      S5     2_post
## 35 1.0000      Q14 Coding      S5     2_post
## 36 0.6667       Q8 Coding      S6     2_post
## 37 0.5000       Q9 Coding      S6     2_post
## 38 0.0000      Q10 Coding      S6     2_post
## 39 0.3333      Q11 Coding      S6     2_post
## 40 0.2500      Q12 Coding      S6     2_post
## 41 0.0000      Q13 Coding      S6     2_post
## 42 0.0000      Q14 Coding      S6     2_post
## 43 0.0000       Q8 Coding      S7     2_post
## 44 1.0000       Q9 Coding      S7     2_post
## 45 1.0000      Q10 Coding      S7     2_post
## 46 1.0000      Q11 Coding      S7     2_post
## 47 1.0000      Q12 Coding      S7     2_post
## 48 1.0000      Q13 Coding      S7     2_post
```

```
## 49 1.0000      Q14 Coding      S7     2_post
## 50 0.6667       Q8 Coding      S8     2_post
## 51 0.5000       Q9 Coding      S8     2_post
## 52 0.0000      Q10 Coding      S8     2_post
## 53 1.0000      Q11 Coding      S8     2_post
## 54 1.0000      Q12 Coding      S8     2_post
## 55 1.0000      Q13 Coding      S8     2_post
## 56 1.0000      Q14 Coding      S8     2_post
## 57 1.0000       Q8 Coding      S9     2_post
## 58 1.0000       Q9 Coding      S9     2_post
## 59 1.0000      Q10 Coding      S9     2_post
## 60 1.0000      Q11 Coding      S9     2_post
## 61 1.0000      Q12 Coding      S9     2_post
## 62 1.0000      Q13 Coding      S9     2_post
## 63 1.0000      Q14 Coding      S9     2_post
## 64 1.0000       Q8 Coding     S10     2_post
## 65 1.0000       Q9 Coding     S10     2_post
## 66 0.0000      Q10 Coding     S10     2_post
## 67 1.0000      Q11 Coding     S10     2_post
## 68 0.5000      Q12 Coding     S10     2_post
## 69 0.0000      Q13 Coding     S10     2_post
## 70 0.0000      Q14 Coding     S10     2_post
## 71 1.0000       Q8 Coding     S11     2_post
## 72 0.5000       Q9 Coding     S11     2_post
## 73 1.0000      Q10 Coding     S11     2_post
## 74 0.6667      Q11 Coding     S11     2_post
## 75 0.5000      Q12 Coding     S11     2_post
## 76 1.0000      Q13 Coding     S11     2_post
## 77 0.0000      Q14 Coding     S11     2_post
## 78 1.0000       Q8 Coding     S12     2_post
## 79 1.0000       Q9 Coding     S12     2_post
## 80 1.0000      Q10 Coding     S12     2_post
## 81 0.6667      Q11 Coding     S12     2_post
## 82 0.5000      Q12 Coding     S12     2_post
## 83 0.0000      Q13 Coding     S12     2_post
## 84 0.0000      Q14 Coding     S12     2_post
## 85 0.3333       Q8 Coding     S14     2_post
## 86 0.5000       Q9 Coding     S14     2_post
## 87 1.0000      Q10 Coding     S14     2_post
## 88 0.6667      Q11 Coding     S14     2_post
## 89 0.5000      Q12 Coding     S14     2_post
## 90 0.0000      Q13 Coding     S14     2_post
## 91 1.0000      Q14 Coding     S14     2_post
```

```
pd_pre <- df_questions_pre %>%
  filter(topic == "ProfDev")
pd_pre
```

```
##     score question   topic student assessment
## 1  1.0000      Q15 ProfDev      S1      1_pre
## 2  1.0000      Q16 ProfDev      S1      1_pre
## 3  1.0000      Q17 ProfDev      S1      1_pre
## 4  0.7500      Q18 ProfDev      S1      1_pre
## 5  0.0000      Q15 ProfDev      S2      1_pre
```

```
## 6  1.0000      Q16 ProfDev      S2      1_pre
## 7  1.0000      Q17 ProfDev      S2      1_pre
## 8  1.0000      Q18 ProfDev      S2      1_pre
## 9  1.0000      Q15 ProfDev      S3      1_pre
## 10 1.0000      Q16 ProfDev      S3      1_pre
## 11 1.0000      Q17 ProfDev      S3      1_pre
## 12 0.7500      Q18 ProfDev      S3      1_pre
## 13 0.4000      Q15 ProfDev      S4      1_pre
## 14 1.0000      Q16 ProfDev      S4      1_pre
## 15 0.6667      Q17 ProfDev      S4      1_pre
## 16 1.0000      Q18 ProfDev      S4      1_pre
## 17 0.4000      Q15 ProfDev      S5      1_pre
## 18 1.0000      Q16 ProfDev      S5      1_pre
## 19 0.8333      Q17 ProfDev      S5      1_pre
## 20 0.7500      Q18 ProfDev      S5      1_pre
## 21 0.4000      Q15 ProfDev      S6      1_pre
## 22 1.0000      Q16 ProfDev      S6      1_pre
## 23 1.0000      Q17 ProfDev      S6      1_pre
## 24 0.7500      Q18 ProfDev      S6      1_pre
## 25 0.6000      Q15 ProfDev      S7      1_pre
## 26 1.0000      Q16 ProfDev      S7      1_pre
## 27 1.0000      Q17 ProfDev      S7      1_pre
## 28 0.7500      Q18 ProfDev      S7      1_pre
## 29 1.0000      Q15 ProfDev      S8      1_pre
## 30 1.0000      Q16 ProfDev      S8      1_pre
## 31 1.0000      Q17 ProfDev      S8      1_pre
## 32 0.7500      Q18 ProfDev      S8      1_pre
## 33 1.0000      Q15 ProfDev      S9      1_pre
## 34 1.0000      Q16 ProfDev      S9      1_pre
## 35 1.0000      Q17 ProfDev      S9      1_pre
## 36 0.5000      Q18 ProfDev      S9      1_pre
## 37 0.4000      Q15 ProfDev     S10      1_pre
## 38 0.8333      Q16 ProfDev     S10      1_pre
## 39 0.5000      Q17 ProfDev     S10      1_pre
## 40 1.0000      Q18 ProfDev     S10      1_pre
## 41 1.0000      Q15 ProfDev     S11      1_pre
## 42 1.0000      Q16 ProfDev     S11      1_pre
## 43 1.0000      Q17 ProfDev     S11      1_pre
## 44 0.7500      Q18 ProfDev     S11      1_pre
## 45 1.0000      Q15 ProfDev     S12      1_pre
## 46 1.0000      Q16 ProfDev     S12      1_pre
## 47 1.0000      Q17 ProfDev     S12      1_pre
## 48 0.7500      Q18 ProfDev     S12      1_pre
## 49 0.2000      Q15 ProfDev     S13      1_pre
## 50 1.0000      Q16 ProfDev     S13      1_pre
## 51 1.0000      Q17 ProfDev     S13      1_pre
## 52 1.0000      Q18 ProfDev     S13      1_pre
```

```
pd_post <- df_questions_post %>%
  filter(topic == "ProfDev")
pd_post
```

```
##     score question   topic student assessment
## 1  1.0000      Q15 ProfDev      S1     2_post
```

```
## 2  1.0000      Q16 ProfDev      S1     2_post
## 3  1.0000      Q17 ProfDev      S1     2_post
## 4  1.0000      Q18 ProfDev      S1     2_post
## 5  0.2000      Q15 ProfDev      S2     2_post
## 6  1.0000      Q16 ProfDev      S2     2_post
## 7  1.0000      Q17 ProfDev      S2     2_post
## 8  0.7500      Q18 ProfDev      S2     2_post
## 9  1.0000      Q15 ProfDev      S3     2_post
## 10 1.0000      Q16 ProfDev      S3     2_post
## 11 1.0000      Q17 ProfDev      S3     2_post
## 12 1.0000      Q18 ProfDev      S3     2_post
## 13 1.0000      Q15 ProfDev      S4     2_post
## 14 1.0000      Q16 ProfDev      S4     2_post
## 15 1.0000      Q17 ProfDev      S4     2_post
## 16 0.7500      Q18 ProfDev      S4     2_post
## 17 0.4000      Q15 ProfDev      S5     2_post
## 18 1.0000      Q16 ProfDev      S5     2_post
## 19 1.0000      Q17 ProfDev      S5     2_post
## 20 0.7500      Q18 ProfDev      S5     2_post
## 21 0.2000      Q15 ProfDev      S6     2_post
## 22 1.0000      Q16 ProfDev      S6     2_post
## 23 1.0000      Q17 ProfDev      S6     2_post
## 24 0.7500      Q18 ProfDev      S6     2_post
## 25 0.6000      Q15 ProfDev      S7     2_post
## 26 1.0000      Q16 ProfDev      S7     2_post
## 27 1.0000      Q17 ProfDev      S7     2_post
## 28 1.0000      Q18 ProfDev      S7     2_post
## 29 1.0000      Q15 ProfDev      S8     2_post
## 30 1.0000      Q16 ProfDev      S8     2_post
## 31 1.0000      Q17 ProfDev      S8     2_post
## 32 0.7500      Q18 ProfDev      S8     2_post
## 33 1.0000      Q15 ProfDev      S9     2_post
## 34 1.0000      Q16 ProfDev      S9     2_post
## 35 1.0000      Q17 ProfDev      S9     2_post
## 36 0.7500      Q18 ProfDev      S9     2_post
## 37 1.0000      Q15 ProfDev     S10     2_post
## 38 0.8333      Q16 ProfDev     S10     2_post
## 39 1.0000      Q17 ProfDev     S10     2_post
## 40 0.7500      Q18 ProfDev     S10     2_post
## 41 1.0000      Q15 ProfDev     S11     2_post
## 42 1.0000      Q16 ProfDev     S11     2_post
## 43 1.0000      Q17 ProfDev     S11     2_post
## 44 1.0000      Q18 ProfDev     S11     2_post
## 45 0.6000      Q15 ProfDev     S12     2_post
## 46 1.0000      Q16 ProfDev     S12     2_post
## 47 1.0000      Q17 ProfDev     S12     2_post
## 48 0.5000      Q18 ProfDev     S12     2_post
## 49 0.6000      Q15 ProfDev     S14     2_post
## 50 1.0000      Q16 ProfDev     S14     2_post
## 51 1.0000      Q17 ProfDev     S14     2_post
## 52 0.7500      Q18 ProfDev     S14     2_post
```

```
# Summarize each stat
summary_bio_pre<- group_by(bio_pre, question) %>%
```

```
  dplyr::summarize(
    count = n(),
    mean = mean(score, na.rm = TRUE),
    sd = sd(score, na.rm = TRUE)
  )
summary_bio_pre
```

```
## # A tibble: 7 x 4
##   question count  mean    sd
##   <chr>    <int> <dbl> <dbl>
## 1 Q1          13 0.692 0.325
## 2 Q2          13 0.385 0.463
## 3 Q3          13 0.708 0.253
## 4 Q4          13 0.641 0.346
## 5 Q5          13 0.654 0.357
## 6 Q6          13 0.692 0.253
## 7 Q7          13 0.615 0.506
```

```
summary_bio_post <- group_by(bio_post, question) %>%
  dplyr::summarize(
    count = n(),
    mean = mean(score, na.rm = TRUE),
    sd = sd(score, na.rm = TRUE)
  )
summary_bio_post
```

```
## # A tibble: 7 x 4
##   question count  mean    sd
##   <chr>    <int> <dbl> <dbl>
## 1 Q1          13 0.808 0.208
## 2 Q2          13 0.808 0.384
## 3 Q3          13 0.923 0.130
## 4 Q4          13 0.538 0.320
## 5 Q5          13 0.769 0.363
## 6 Q6          13 0.846 0.220
## 7 Q7          13 0.846 0.376
```

```
summary_coding_pre<- group_by(coding_pre, question) %>%
  dplyr::summarize(
    count = n(),
    mean = mean(score, na.rm = TRUE),
    sd = sd(score, na.rm = TRUE)
  )
summary_coding_pre
```

```
## # A tibble: 7 x 4
##   question count  mean    sd
##   <chr>    <int> <dbl> <dbl>
## 1 Q10         13 0.231 0.439
## 2 Q11         13 0.692 0.318
## 3 Q12         13 0.442 0.291
```

```
## 4 Q13         13 0.615 0.506
## 5 Q14         13 0.615 0.506
## 6 Q8          13 0.795 0.256
## 7 Q9          13 0.731 0.330
```

```
summary_coding_post<- group_by(coding_post, question) %>%
  dplyr::summarize(
    count = n(),
    mean = mean(score, na.rm = TRUE),
    sd = sd(score, na.rm = TRUE)
  )
summary_coding_post
```

```
## # A tibble: 7 x 4
##   question count  mean    sd
##   <chr>    <int> <dbl> <dbl>
## 1 Q10         13 0.769 0.439
## 2 Q11         13 0.744 0.338
## 3 Q12         13 0.654 0.261
## 4 Q13         13 0.692 0.480
## 5 Q14         13 0.615 0.506
## 6 Q8          13 0.692 0.346
## 7 Q9          13 0.731 0.259
```

```
summary_pd_pre<- group_by(pd_pre, question) %>%
  dplyr::summarize(
    count = n(),
    mean = mean(score, na.rm = TRUE),
    sd = sd(score, na.rm = TRUE)
  )
summary_pd_pre
```

```
## # A tibble: 4 x 4
##   question count  mean     sd
##   <chr>    <int> <dbl>  <dbl>
## 1 Q15         13 0.646 0.367
## 2 Q16         13 0.987 0.0462
## 3 Q17         13 0.923 0.161
## 4 Q18         13 0.808 0.150
```

```
summary_pd_post<- group_by(pd_post, question) %>%
  dplyr::summarize(
    count = n(),
    mean = mean(score, na.rm = TRUE),
    sd = sd(score, na.rm = TRUE)
  )
summary_pd_post
```

```
## # A tibble: 4 x 4
##   question count  mean     sd
##   <chr>    <int> <dbl>  <dbl>
## 1 Q15         13 0.738 0.320
```

```
## 2 Q16         13 0.987 0.0462
## 3 Q17         13 1     0
## 4 Q18         13 0.808 0.150
```

```
# Import scores by question with questions as the column
# headers and find the average

questions_wide_pre <- read_csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/
```

Paired boxplots to show average question performance by topic

```
## Rows: 13 Columns: 19
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (1): student
## dbl (18): Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14, Q15, ...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
questions_wide_post <- read_csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis
```

```
## Rows: 13 Columns: 19
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (1): student
## dbl (18): Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14, Q15, ...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
# create a prescore dataframe
qmu1_pre <- ddply(questions_pre, "Question", summarise, grp.mean = mean(Score))
qmu1_pre
```

```
##    Question grp.mean
## 1        Q1   0.6923
## 2       Q10   0.2308
## 3       Q11   0.6923
## 4       Q12   0.4423
## 5       Q13   0.6154
## 6       Q14   0.6154
## 7       Q15   0.6462
## 8       Q16   0.9872
## 9       Q17   0.9231
## 10      Q18   0.8077
## 11       Q2   0.3846
## 12       Q3   0.7077
## 13       Q4   0.6410
```

```
## 14       Q5   0.6538
## 15       Q6   0.6923
## 16       Q7   0.6154
## 17       Q8   0.7949
## 18       Q9   0.7308
```

```
# create a postscore dataframe
qmu2_post <- ddply(questions_post, "Question", summarise, grp.mean = mean(Score))
qmu2_post
```

```
##    Question grp.mean
## 1        Q1   0.8077
## 2       Q10   0.7692
## 3       Q11   0.7436
## 4       Q12   0.6538
## 5       Q13   0.6923
## 6       Q14   0.6154
## 7       Q15   0.7385
## 8       Q16   0.9872
## 9       Q17   1.0000
## 10      Q18   0.8077
## 11       Q2   0.8077
## 12       Q3   0.9231
## 13       Q4   0.5385
## 14       Q5   0.7692
## 15       Q6   0.8462
## 16       Q7   0.8462
## 17       Q8   0.6923
## 18       Q9   0.7308
```

```
# merge the dataframes and find the mean
qmu <- data.frame(group = rep(c("qmu1_pre", "qmu2_post"), each = 18),
    score = c(qmu1_pre$grp.mean, qmu2_post$grp.mean), question = c(qmu1_pre$Question,
        qmu2_post$Question))

# set the order for the plot
qmu$question <- factor(qmu$question, levels = c("Q1", "Q2", "Q3",
    "Q4", "Q5", "Q6", "Q7", "Q8", "Q9", "Q10", "Q11", "Q12",
    "Q13", "Q14", "Q15", "Q16", "Q17", "Q18"))

# check the order
qmu
```

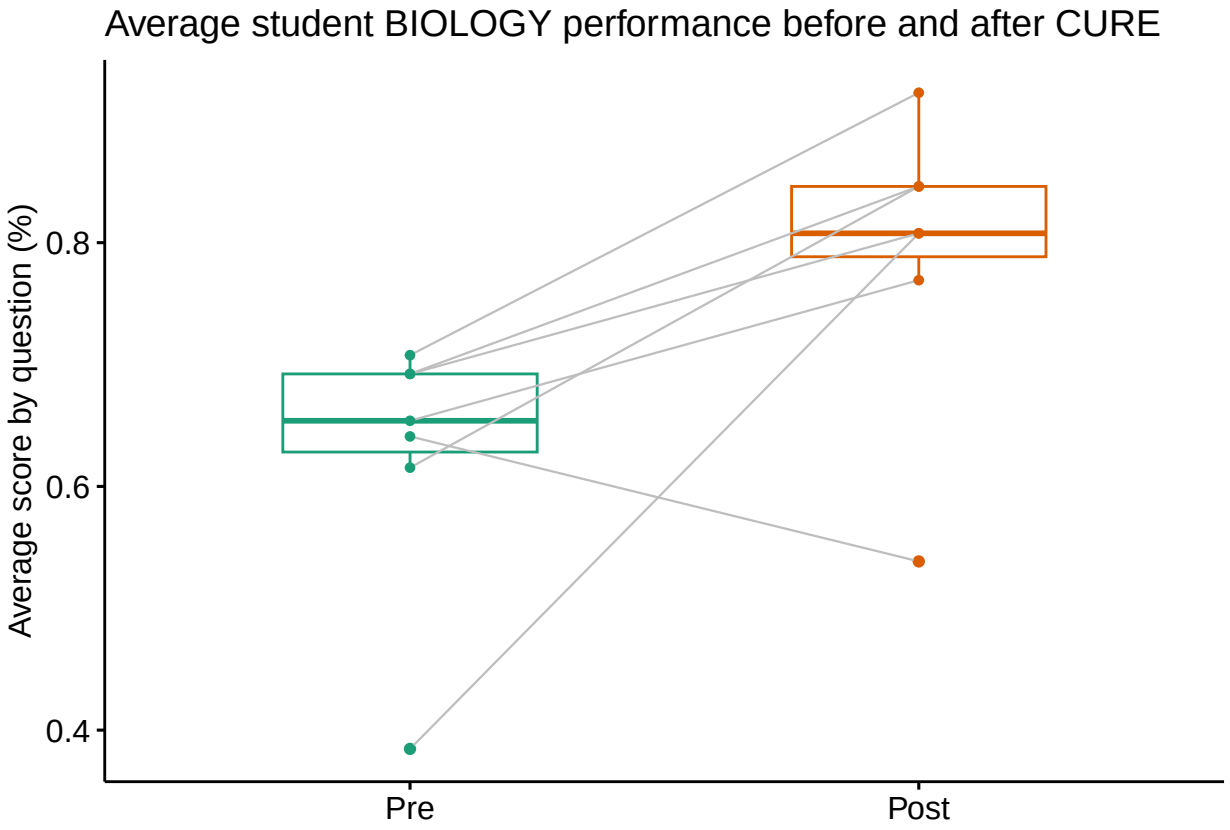
```
##        group  score question
## 1   qmu1_pre 0.6923       Q1
## 2   qmu1_pre 0.2308      Q10
## 3   qmu1_pre 0.6923      Q11
## 4   qmu1_pre 0.4423      Q12
## 5   qmu1_pre 0.6154      Q13
## 6   qmu1_pre 0.6154      Q14
## 7   qmu1_pre 0.6462      Q15
## 8   qmu1_pre 0.9872      Q16
## 9   qmu1_pre 0.9231      Q17
```

```
## 10  qmu1_pre 0.8077      Q18
## 11  qmu1_pre 0.3846       Q2
## 12  qmu1_pre 0.7077       Q3
## 13  qmu1_pre 0.6410       Q4
## 14  qmu1_pre 0.6538       Q5
## 15  qmu1_pre 0.6923       Q6
## 16  qmu1_pre 0.6154       Q7
## 17  qmu1_pre 0.7949       Q8
## 18  qmu1_pre 0.7308       Q9
## 19 qmu2_post 0.8077       Q1
## 20 qmu2_post 0.7692      Q10
## 21 qmu2_post 0.7436      Q11
## 22 qmu2_post 0.6538      Q12
## 23 qmu2_post 0.6923      Q13
## 24 qmu2_post 0.6154      Q14
## 25 qmu2_post 0.7385      Q15
## 26 qmu2_post 0.9872      Q16
## 27 qmu2_post 1.0000      Q17
## 28 qmu2_post 0.8077      Q18
## 29 qmu2_post 0.8077       Q2
## 30 qmu2_post 0.9231       Q3
## 31 qmu2_post 0.5385       Q4
## 32 qmu2_post 0.7692       Q5
## 33 qmu2_post 0.8462       Q6
## 34 qmu2_post 0.8462       Q7
## 35 qmu2_post 0.6923       Q8
## 36 qmu2_post 0.7308       Q9
```

```
# Create the dataframe for bio
bio_all <- data.frame(score = c(bio_pre$score, bio_post$score),
    question = c(bio_pre$question, bio_post$question), topic = c(bio_pre$topic,
        bio_post$topic), student = c(bio_pre$student, bio_post$student),
    group = c(bio_pre$assessment, bio_post$assessment))

bio_qmu <- data.frame(qmu) %>%
    filter(!question %in% c("Q8", "Q9", "Q10", "Q11", "Q12",
        "Q13", "Q14", "Q15", "Q16", "Q17", "Q18"))
bio_qmu
```

```
##        group  score question
## 1   qmu1_pre 0.6923       Q1
## 2   qmu1_pre 0.3846       Q2
## 3   qmu1_pre 0.7077       Q3
## 4   qmu1_pre 0.6410       Q4
## 5   qmu1_pre 0.6538       Q5
## 6   qmu1_pre 0.6923       Q6
## 7   qmu1_pre 0.6154       Q7
## 8  qmu2_post 0.8077       Q1
## 9  qmu2_post 0.8077       Q2
## 10 qmu2_post 0.9231       Q3
## 11 qmu2_post 0.5385       Q4
## 12 qmu2_post 0.7692       Q5
## 13 qmu2_post 0.8462       Q6
## 14 qmu2_post 0.8462       Q7
```

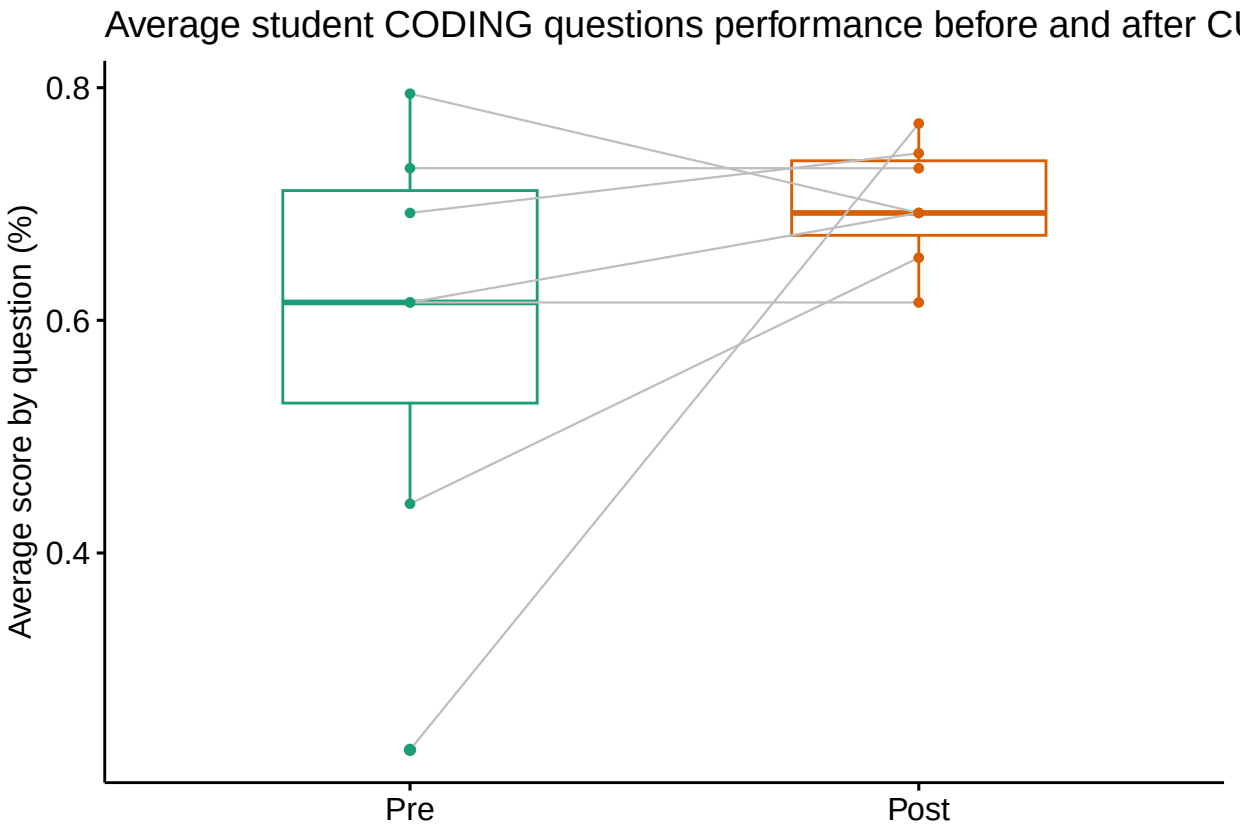
```
# Create the paired boxplots for bio
bio_paired <- ggpaired(bio_qmu, x = "group", y = "score", color = "group",
    shape = "question", line.color = "gray", line.size = 0.4,
    palette = "Dark2", title = "Average student BIOLOGY performance before and after CURE",
    xlab = "Assessment", ylab = "Average score by question (%)") +
    theme(legend.position = "none") + scale_x_discrete(labels = c(qmu1_pre = "Pre",
    qmu2_post = "Post"), name = element_blank())
bio_paired
```




```
# filter(qmu$question == 'Q1', 'Q2', 'Q3', 'Q4', 'Q5',
# 'Q6', 'Q7') %>%


# Create the dataframe for coding
coding_all <- data.frame(score = c(coding_pre$score, coding_post$score),
    question = c(coding_pre$question, coding_post$question),
    topic = c(coding_pre$topic, coding_post$topic), student = c(coding_pre$student,
        coding_post$student), group = c(coding_pre$assessment,
        coding_post$assessment))

coding_qmu <- data.frame(qmu) %>%
    filter(!question %in% c("Q1", "Q2", "Q3", "Q4", "Q5", "Q6",
        "Q7", "Q15", "Q16", "Q17", "Q18"))
coding_qmu
```

```
##        group  score question
## 1   qmu1_pre 0.2308      Q10
## 2   qmu1_pre 0.6923      Q11
## 3   qmu1_pre 0.4423      Q12
## 4   qmu1_pre 0.6154      Q13
## 5   qmu1_pre 0.6154      Q14
## 6   qmu1_pre 0.7949       Q8
## 7   qmu1_pre 0.7308       Q9
## 8  qmu2_post 0.7692      Q10
## 9  qmu2_post 0.7436      Q11
## 10 qmu2_post 0.6538      Q12
## 11 qmu2_post 0.6923      Q13
## 12 qmu2_post 0.6154      Q14
## 13 qmu2_post 0.6923       Q8
## 14 qmu2_post 0.7308       Q9
```

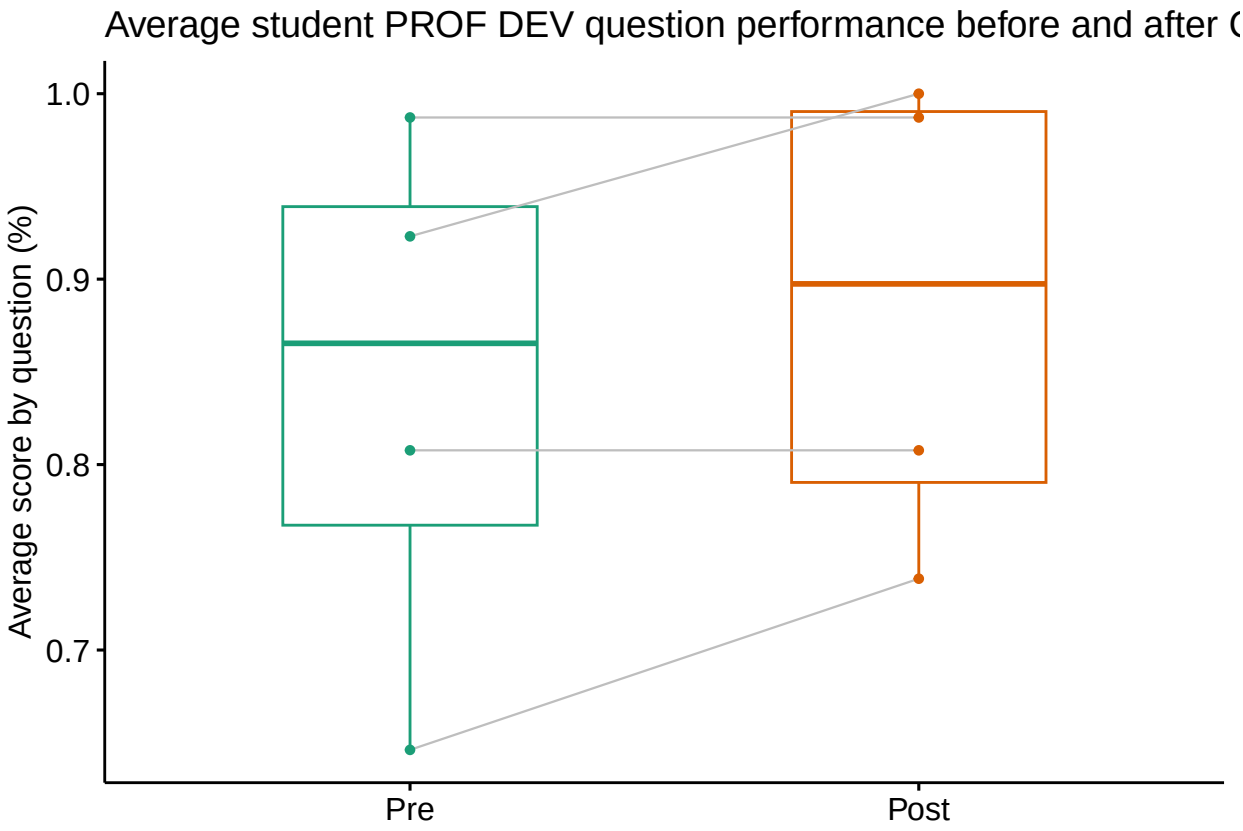
```r
# Create the paired boxplots for coding
coding_paired <- ggpaired(coding_qmu, x = "group", y = "score",
    color = "group", line.color = "gray", line.size = 0.4, palette = "Dark2",
    title = "Average student CODING questions performance before and after CURE",
    xlab = "Assessment", ylab = "Average score by question (%)") +
    theme(legend.position = "none") + scale_x_discrete(labels = c(qmu1_pre = "Pre",
    qmu2_post = "Post"), name = element_blank())
coding_paired
```



```r
# Create the dataframe for pd
pd_all <- data.frame(score = c(pd_pre$score, pd_post$score),
    question = c(pd_pre$question, pd_post$question), topic = c(pd_pre$topic,
        pd_post$topic), student = c(pd_pre$student, pd_post$student),
    group = c(pd_pre$assessment, pd_post$assessment))

pd_qmu <- data.frame(qmu) %>%
    filter(!question %in% c("Q1", "Q2", "Q3", "Q4", "Q5", "Q6",
        "Q7", "Q8", "Q9", "Q10", "Q11", "Q12", "Q13", "Q14"))
pd_qmu
```

```
##       group  score question
## 1  qmu1_pre 0.6462      Q15
## 2  qmu1_pre 0.9872      Q16
## 3  qmu1_pre 0.9231      Q17
## 4  qmu1_pre 0.8077      Q18
## 5 qmu2_post 0.7385      Q15
## 6 qmu2_post 0.9872      Q16
## 7 qmu2_post 1.0000      Q17
## 8 qmu2_post 0.8077      Q18
```

```r
# Create the paired boxplots for pd
pd_paired <- ggpaired(pd_qmu, x = "group", y = "score", color = "group",
    shape = "question", line.color = "gray", line.size = 0.4,
    palette = "Dark2", title = "Average student PROF DEV question performance before and after CURE",
    xlab = "Assessment", ylab = "Average score by question (%)") +
    theme(legend.position = "none") + scale_x_discrete(labels = c(qmu1_pre = "Pre",
    qmu2_post = "Post"), name = element_blank())
pd_paired
```



T-test by topic

```
# Shapiro-Wilk normality test
shapiro.test(bio_post$score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  bio_post$score
## W = 0.7, p-value = 3e-12
```

```
shapiro.test(bio_pre$score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  bio_pre$score
## W = 0.84, p-value = 1e-08
```

```
# Shapiro-Wilk normality test
shapiro.test(coding_post$score)
```

```
##
##  Shapiro-Wilk normality test
##
```

```
## data:  coding_post$score
## W = 0.75, p-value = 3e-11
```

```
shapiro.test(coding_pre$score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  coding_pre$score
## W = 0.79, p-value = 4e-10
```

```
# Shapiro-Wilk normality test
shapiro.test(pd_post$score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  pd_post$score
## W = 0.63, p-value = 3e-10
```

```
shapiro.test(pd_pre$score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  pd_pre$score
## W = 0.7, p-value = 5e-09
```

```
bio_ttest <- t.test(bio_post$score, bio_pre$score, paired = TRUE,
    alternative = "two.sided")
bio_ttest
```

```
##
##  Paired t-test
##
## data:  bio_post$score and bio_pre$score
## t = 3.6, df = 90, p-value = 5e-04
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  0.07408 0.25486
## sample estimates:
## mean difference
##          0.1645
```

```
coding_ttest <- t.test(coding_post$score, coding_pre$score, paired = TRUE,
    alternative = "two.sided")
coding_ttest
```

```
##
##  Paired t-test
```

```
##
## data:  coding_post$score and coding_pre$score
## t = 2.2, df = 90, p-value = 0.03
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  0.01148 0.21013
## sample estimates:
## mean difference
##          0.1108
```

```
pd_ttest <- t.test(pd_post$score, pd_pre$score, paired = TRUE,
    alternative = "two.sided")
pd_ttest
```

```
##
##  Paired t-test
##
## data:  pd_post$score and pd_pre$score
## t = 1.5, df = 51, p-value = 0.1
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  -0.01338  0.09800
## sample estimates:
## mean difference
##         0.04231
```

Question summaries

```
# Create summaries of before and after score results of
# each question
questions_wide_pre
```

```
## # A tibble: 13 x 19
##    student    Q1    Q2    Q3    Q4    Q5    Q6    Q7    Q8    Q9   Q10   Q11
##    <chr>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
##  1 S1       0.5    0     1   1     1     1         1 0.667   1       1 0.333
##  2 S2       1      0     0.4 0.333 0.5   0.667     1 1       0.5     0 0.667
##  3 S3       0.25   0     0.6 0     0.167 0.667     1 0.333   1       0 0.667
##  4 S4       1      1     0.8 1     0.167 1         1 1       0.5     1 1
##  5 S5       0.75   1     0.6 0.333 0.5   0.667     1 1       0.5     0 0.667
##  6 S6       0.25   0     0.4 0.667 1     0.333     1 0.667   0.5     0 0.333
##  7 S7       1      0.5   1   1     1     1         1 0.333   1       1 1
##  8 S8       1      1     0.4 0.667 1     0.333     0 1       1       0 0.667
##  9 S9       1      0.5   0.8 0.333 1     0.667     0 1       0.5     0 1
## 10 S10      0.5    0     0.8 0.333 0.5   0.333     0 0.667   1       0 0.667
## 11 S11      1      1     1   1     0.167 1         1 1       1       0 1
## 12 S12      0.25   0     0.4 0.667 0.5   0.667     0 0.667   0       0 0
## 13 S13      0.5    0     1   1     1     0.667     0 1       1       0 1
## # i 7 more variables: Q12 <dbl>, Q13 <dbl>, Q14 <dbl>, Q15 <dbl>, Q16 <dbl>,
## #   Q17 <dbl>, Q18 <dbl>
```

```
questions_wide_post
```

```
## # A tibble: 13 x 19
##    student    Q1    Q2    Q3    Q4    Q5    Q6    Q7    Q8    Q9   Q10   Q11
##    <chr>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
##  1 S1       0.5    0.5   1   0.667 1     1         1 0.667   1       1 1
##  2 S2       0.75   1     0.8 0.333 0.667 0.667     1 1       0.5     1 0
##  3 S3       1      1     1   1     1     1         1 0.333   1       1 1
##  4 S4       1      1     1   0.667 1     1         1 1       0.5     1 0.333
##  5 S5       0.75   1     0.8 0.333 1     0.667     1 0.333   0.5     1 1
##  6 S6       0.5    1     1   0.667 0     0.667     0 0.667   0.5     0 0.333
##  7 S7       1      1     1   1     1     1         1 0       1       1 1
##  8 S8       1      1     0.8 0.667 0.833 1         1 0.667   0.5     0 1
##  9 S9       1      1     1   0.667 1     1         1 1       1       1 1
## 10 S10      0.75   1     1   0     0.333 1         0 1       1       0 1
## 11 S11      1      1     1   0.333 1     1         1 1       0.5     1 0.667
## 12 S12      0.5    0     0.6 0.667 0.167 0.333     1 1       1       1 0.667
## 13 S13      0.75   0     1   0     1     0.667     1 0.333   0.5     1 0.667
## # i 7 more variables: Q12 <dbl>, Q13 <dbl>, Q14 <dbl>, Q15 <dbl>, Q16 <dbl>,
## #   Q17 <dbl>, Q18 <dbl>
```

```
question_summary_pre <- summary(questions_wide_pre)
question_summary_pre
```

```
##    student                Q1              Q2              Q3
##  Length:13          Min.   :0.250   Min.   :0.000   Min.   :0.400
##  Class :character   1st Qu.:0.500   1st Qu.:0.000   1st Qu.:0.400
##  Mode  :character   Median :0.750   Median :0.000   Median :0.800
##                     Mean   :0.692   Mean   :0.385   Mean   :0.708
##                     3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##                     Max.   :1.000   Max.   :1.000   Max.   :1.000
##        Q4              Q5              Q6              Q7
##  Min.   :0.000   Min.   :0.167   Min.   :0.333   Min.   :0.000
##  1st Qu.:0.333   1st Qu.:0.500   1st Qu.:0.667   1st Qu.:0.000
##  Median :0.667   Median :0.500   Median :0.667   Median :1.000
##  Mean   :0.641   Mean   :0.654   Mean   :0.692   Mean   :0.615
##  3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##        Q8              Q9             Q10             Q11
##  Min.   :0.333   Min.   :0.000   Min.   :0.000   Min.   :0.000
##  1st Qu.:0.667   1st Qu.:0.500   1st Qu.:0.000   1st Qu.:0.667
##  Median :1.000   Median :1.000   Median :0.000   Median :0.667
##  Mean   :0.795   Mean   :0.731   Mean   :0.231   Mean   :0.692
##  3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:0.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##       Q12             Q13             Q14             Q15
##  Min.   :0.000   Min.   :0.000   Min.   :0.000   Min.   :0.000
##  1st Qu.:0.250   1st Qu.:0.000   1st Qu.:0.000   1st Qu.:0.400
##  Median :0.500   Median :1.000   Median :1.000   Median :0.600
##  Mean   :0.442   Mean   :0.615   Mean   :0.615   Mean   :0.646
##  3rd Qu.:0.500   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
```

```
##       Q16             Q17             Q18
##  Min.   :0.833   Min.   :0.500   Min.   :0.500
##  1st Qu.:1.000   1st Qu.:1.000   1st Qu.:0.750
##  Median :1.000   Median :1.000   Median :0.750
##  Mean   :0.987   Mean   :0.923   Mean   :0.808
##  3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000
```

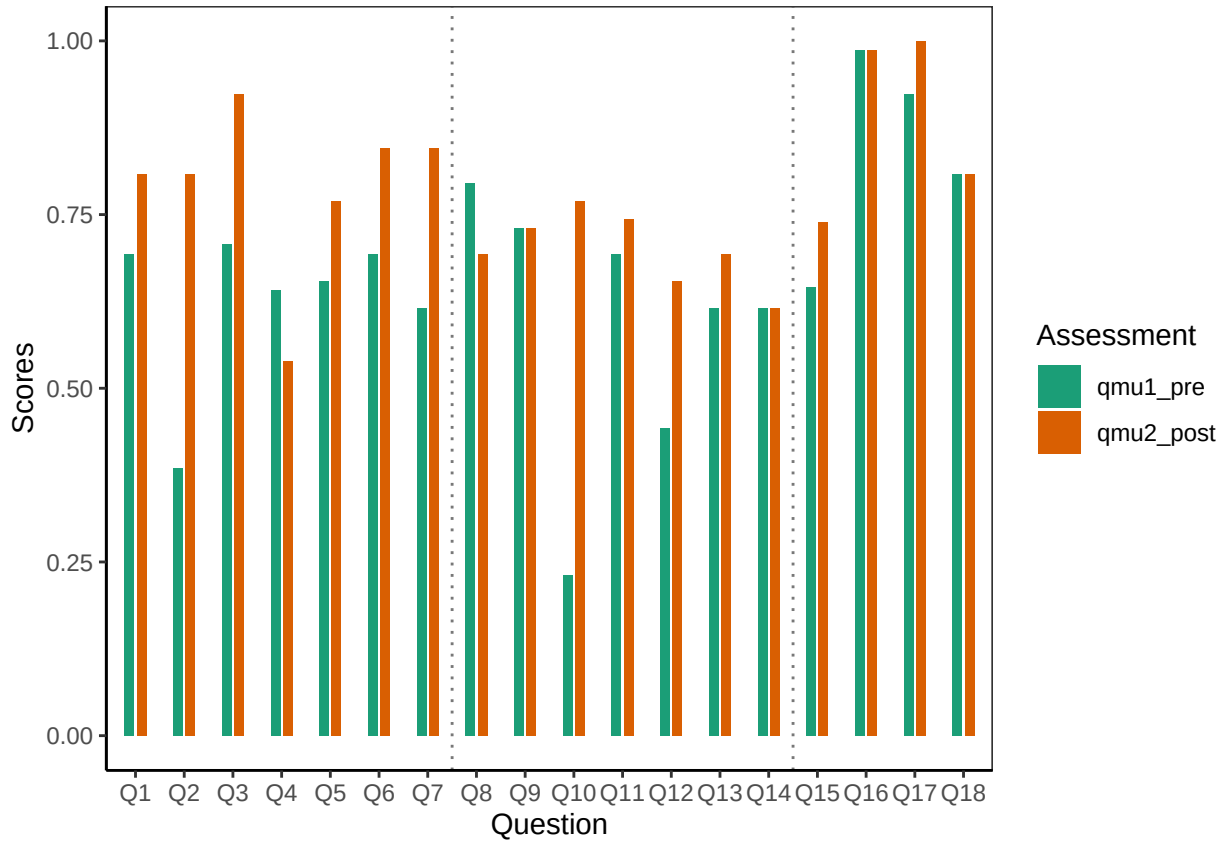
```
question_summary_post <- summary(questions_wide_post)
question_summary_post
```

```
##    student                Q1              Q2              Q3
##  Length:13          Min.   :0.500   Min.   :0.000   Min.   :0.600
##  Class :character   1st Qu.:0.750   1st Qu.:1.000   1st Qu.:0.800
##  Mode  :character   Median :0.750   Median :1.000   Median :1.000
##                     Mean   :0.808   Mean   :0.808   Mean   :0.923
##                     3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##                     Max.   :1.000   Max.   :1.000   Max.   :1.000
##        Q4              Q5              Q6              Q7
##  Min.   :0.000   Min.   :0.000   Min.   :0.333   Min.   :0.000
##  1st Qu.:0.333   1st Qu.:0.667   1st Qu.:0.667   1st Qu.:1.000
##  Median :0.667   Median :1.000   Median :1.000   Median :1.000
##  Mean   :0.538   Mean   :0.769   Mean   :0.846   Mean   :0.846
##  3rd Qu.:0.667   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##        Q8              Q9             Q10             Q11
##  Min.   :0.000   Min.   :0.500   Min.   :0.000   Min.   :0.000
##  1st Qu.:0.333   1st Qu.:0.500   1st Qu.:1.000   1st Qu.:0.667
##  Median :0.667   Median :0.500   Median :1.000   Median :1.000
##  Mean   :0.692   Mean   :0.731   Mean   :0.769   Mean   :0.744
##  3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##       Q12             Q13             Q14             Q15
##  Min.   :0.250   Min.   :0.000   Min.   :0.000   Min.   :0.200
##  1st Qu.:0.500   1st Qu.:0.000   1st Qu.:0.000   1st Qu.:0.600
##  Median :0.500   Median :1.000   Median :1.000   Median :1.000
##  Mean   :0.654   Mean   :0.692   Mean   :0.615   Mean   :0.739
##  3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##       Q16             Q17         Q18
##  Min.   :0.833   Min.   :1   Min.   :0.500
##  1st Qu.:1.000   1st Qu.:1   1st Qu.:0.750
##  Median :1.000   Median :1   Median :0.750
##  Mean   :0.987   Mean   :1   Mean   :0.808
##  3rd Qu.:1.000   3rd Qu.:1   3rd Qu.:1.000
##  Max.   :1.000   Max.   :1   Max.   :1.000
```

Barplot by question

```
# Barplot option A plot the questions
questions_bar <- ggplot(data = qmu, aes(x = question, y = score,
```

```
    fill = group, palette = "Dark2")) + geom_bar(width = 0.4,
    stat = "identity", position = position_dodge(0.5)) + scale_fill_brewer(palette = "Dark2") +
    xlab("Question") + ylab("Scores") + labs(fill = "Assessment") +
    theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
        panel.background = element_blank(), axis.line = element_line(colour = "black")) +
    geom_vline(xintercept = 7.5, color = "gray47", linetype = 3) +
    geom_vline(xintercept = 14.5, color = "gray47", linetype = 3)


questions_bar
```




```
# Barplot option B Add question categories to the qmu table
qmu_topic <- data.frame(qmu)
# Add additional
qmu_topic <- data.frame(qmu_topic, topic = as.character(qmu_topic$question))

# Does not work.  qmu_topic$topic[qmu_topic$topic ==
# c('Q1', 'Q2', 'Q3', 'Q4', 'Q5', 'Q6', 'Q7')] <- 'Biology'

# Replace question number with topic under the topic column
# one by one Biology Q1 - Q7
qmu_topic$topic[qmu_topic$topic == "Q1"] <- "Biology"
qmu_topic$topic[qmu_topic$topic == "Q2"] <- "Biology"
qmu_topic$topic[qmu_topic$topic == "Q3"] <- "Biology"
qmu_topic$topic[qmu_topic$topic == "Q4"] <- "Biology"
```

```r
qmu_topic$topic[qmu_topic$topic == "Q5"] <- "Biology"
qmu_topic$topic[qmu_topic$topic == "Q6"] <- "Biology"
qmu_topic$topic[qmu_topic$topic == "Q7"] <- "Biology"

## Coding Q8 - Q14
qmu_topic$topic[qmu_topic$topic == "Q8"] <- "Coding"
qmu_topic$topic[qmu_topic$topic == "Q9"] <- "Coding"
qmu_topic$topic[qmu_topic$topic == "Q10"] <- "Coding"
qmu_topic$topic[qmu_topic$topic == "Q11"] <- "Coding"
qmu_topic$topic[qmu_topic$topic == "Q12"] <- "Coding"
qmu_topic$topic[qmu_topic$topic == "Q13"] <- "Coding"
qmu_topic$topic[qmu_topic$topic == "Q14"] <- "Coding"

# Professional Development Q15 - Q18
qmu_topic$topic[qmu_topic$topic == "Q15"] <- "ProfDev"
qmu_topic$topic[qmu_topic$topic == "Q16"] <- "ProfDev"
qmu_topic$topic[qmu_topic$topic == "Q17"] <- "ProfDev"
qmu_topic$topic[qmu_topic$topic == "Q18"] <- "ProfDev"

qmu_topic
```

```
##        group  score question   topic
## 1   qmu1_pre 0.6923       Q1 Biology
## 2   qmu1_pre 0.2308      Q10  Coding
## 3   qmu1_pre 0.6923      Q11  Coding
## 4   qmu1_pre 0.4423      Q12  Coding
## 5   qmu1_pre 0.6154      Q13  Coding
## 6   qmu1_pre 0.6154      Q14  Coding
## 7   qmu1_pre 0.6462      Q15 ProfDev
## 8   qmu1_pre 0.9872      Q16 ProfDev
## 9   qmu1_pre 0.9231      Q17 ProfDev
## 10  qmu1_pre 0.8077      Q18 ProfDev
## 11  qmu1_pre 0.3846       Q2 Biology
## 12  qmu1_pre 0.7077       Q3 Biology
## 13  qmu1_pre 0.6410       Q4 Biology
## 14  qmu1_pre 0.6538       Q5 Biology
## 15  qmu1_pre 0.6923       Q6 Biology
## 16  qmu1_pre 0.6154       Q7 Biology
## 17  qmu1_pre 0.7949       Q8  Coding
## 18  qmu1_pre 0.7308       Q9  Coding
## 19 qmu2_post 0.8077       Q1 Biology
## 20 qmu2_post 0.7692      Q10  Coding
## 21 qmu2_post 0.7436      Q11  Coding
## 22 qmu2_post 0.6538      Q12  Coding
## 23 qmu2_post 0.6923      Q13  Coding
## 24 qmu2_post 0.6154      Q14  Coding
## 25 qmu2_post 0.7385      Q15 ProfDev
## 26 qmu2_post 0.9872      Q16 ProfDev
## 27 qmu2_post 1.0000      Q17 ProfDev
## 28 qmu2_post 0.8077      Q18 ProfDev
## 29 qmu2_post 0.8077       Q2 Biology
## 30 qmu2_post 0.9231       Q3 Biology
## 31 qmu2_post 0.5385       Q4 Biology
```

```
## 32 qmu2_post 0.7692       Q5 Biology
## 33 qmu2_post 0.8462       Q6 Biology
## 34 qmu2_post 0.8462       Q7 Biology
## 35 qmu2_post 0.6923       Q8  Coding
## 36 qmu2_post 0.7308       Q9  Coding
```

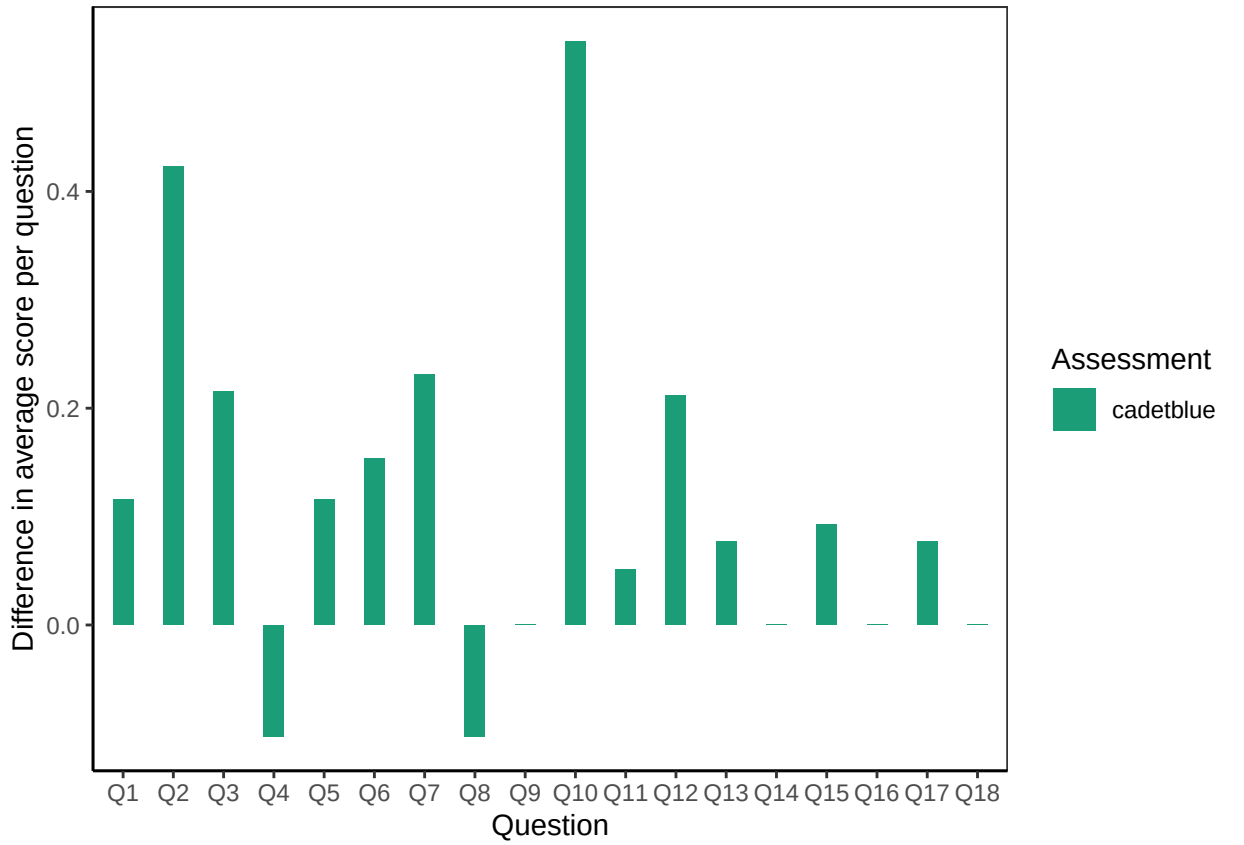
```
# plot the questions
questions_bar_grid <- ggplot(data = qmu_topic, aes(x = question,
    y = score, fill = group, palette = "Dark2")) + geom_bar(width = 0.4,
    stat = "identity", position = position_dodge(0.5)) + scale_fill_brewer(palette = "Dark2",
    labels = c("pre", "post")) + xlab("Question") + ylab("Scores") +
    labs(fill = "Assessment") + theme(legend.position = "bottom",
    panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
    panel.background = element_blank(), axis.line = element_line(colour = "black")) +
    facet_grid(. ~ topic, scales = "free_x", space = "free_x") +
    theme(legend.text = element_text(size = 12), strip.text.x = element_text(face = "bold",
        size = 12), legend.position = "bottom", axis.text = element_text(face = "bold",
        size = 12), axis.text.y.left = element_text(size = 12),
        plot.background = element_rect(color = "black"))



# Plot the differences in average scores
question_diff <- data.frame(diff = qmu2_post$grp.mean - qmu1_pre$grp.mean,
    question = qmu2_post$Question)
question_diff
```

```
##        diff question
## 1   0.11538       Q1
## 2   0.53846      Q10
## 3   0.05128      Q11
## 4   0.21154      Q12
## 5   0.07692      Q13
## 6   0.00000      Q14
## 7   0.09231      Q15
## 8   0.00000      Q16
## 9   0.07692      Q17
## 10  0.00000      Q18
## 11  0.42308       Q2
## 12  0.21538       Q3
## 13 -0.10256       Q4
## 14  0.11538       Q5
## 15  0.15385       Q6
## 16  0.23077       Q7
## 17 -0.10256       Q8
## 18  0.00000       Q9
```

```
# set the order for the plot
question_diff$question <- factor(question_diff$question, levels = c("Q1",
    "Q2", "Q3", "Q4", "Q5", "Q6", "Q7", "Q8", "Q9", "Q10", "Q11",
    "Q12", "Q13", "Q14", "Q15", "Q16", "Q17", "Q18"))

# check the order
question_diff
```

```
##        diff question
## 1   0.11538       Q1
## 2   0.53846      Q10
## 3   0.05128      Q11
## 4   0.21154      Q12
## 5   0.07692      Q13
## 6   0.00000      Q14
## 7   0.09231      Q15
## 8   0.00000      Q16
## 9   0.07692      Q17
## 10  0.00000      Q18
## 11  0.42308       Q2
## 12  0.21538       Q3
## 13 -0.10256       Q4
## 14  0.11538       Q5
## 15  0.15385       Q6
## 16  0.23077       Q7
## 17 -0.10256       Q8
## 18  0.00000       Q9
```

```
question_diff_bar <- ggplot(data = question_diff, aes(x = question,
    y = diff, fill = "cadetblue")) + geom_bar(width = 0.4, stat = "identity",
    position = position_dodge(0.5)) + scale_fill_brewer(palette = "Dark2") +
    xlab("Question") + ylab("Difference in average score per question") +
    labs(fill = "Assessment") + theme(panel.grid.major = element_blank(),
    panel.grid.minor = element_blank(), panel.background = element_blank(),
    axis.line = element_line(colour = "black"))
question_diff_bar
```




```
# save the questions by difference
questions_higher_average <- data.frame(question_diff) %>%
    filter(question_diff$diff > 0)
questions_higher_average
```

```
##       diff question
## 1  0.11538       Q1
## 2  0.53846      Q10
## 3  0.05128      Q11
## 4  0.21154      Q12
## 5  0.07692      Q13
## 6  0.09231      Q15
## 7  0.07692      Q17
## 8  0.42308       Q2
## 9  0.21538       Q3
## 10 0.11538       Q5
## 11 0.15385       Q6
## 12 0.23077       Q7
```

```
questions_nodiff_average <- data.frame(question_diff) %>%
    filter(question_diff$diff == 0)
questions_nodiff_average
```

```
##   diff question
## 1    0      Q14
```

```
## 2    0      Q16
## 3    0      Q18
## 4    0       Q9
```

```
questions_lower_average <- data.frame(question_diff) %>%
    filter(question_diff$diff < 0)
questions_lower_average
```

```
##      diff question
## 1 -0.1026       Q4
## 2 -0.1026       Q8
```

Difference in scores by question

The Bland - Altman plot to quantify agreement between two quantitative measurements by constructing limits of agreement.

```
# sample t-test by question
q1_ttest <- t.test(questions_wide_pre$Q1, questions_wide_post$Q1,
    paired = TRUE, alternative = "two.sided")
q1_ttest
```

```
##
##  Paired t-test
##
## data:  questions_wide_pre$Q1 and questions_wide_post$Q1
## t = -1.7, df = 12, p-value = 0.1
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  -0.26154  0.03077
## sample estimates:
## mean difference
##         -0.1154
```

```
# Matrix test to check gains for each question Remove
# student info column
pre_question_scores <- questions_wide_pre[, -1]
post_question_scores <- questions_wide_post[, -1]

# Create a new table with the results of the t.test
questions_all_summary <- col_t_paired(post_question_scores, pre_question_scores)
```

```
## Warning: col_t_paired: 1 of the columns had essentially constant values.
## First occurrence at column 16
```

```
questions_all_summary
```

```
##     obs.x obs.y obs.paired mean.x mean.y mean.diff    var.x    var.y var.diff
## Q1     13    13         13 0.8077 0.6923   0.11538 0.043269 0.105769  0.05849
## Q2     13    13         13 0.8077 0.3846   0.42308 0.147436 0.214744  0.20192
```

```
## Q3     13    13         13 0.9231 0.7077   0.21538 0.016923 0.064103  0.03641
## Q4     13    13         13 0.5385 0.6410  -0.10256 0.102564 0.119658  0.22934
## Q5     13    13         13 0.7692 0.6538   0.11538 0.132123 0.127137  0.27956
## Q6     13    13         13 0.8462 0.6923   0.15385 0.048433 0.064103  0.08547
## Q7     13    13         13 0.8462 0.6154   0.23077 0.141026 0.256410  0.35897
## Q8     13    13         13 0.6923 0.7949  -0.10256 0.119658 0.065527  0.09972
## Q9     13    13         13 0.7308 0.7308   0.00000 0.067308 0.108974  0.16667
## Q10    13    13         13 0.7692 0.2308   0.53846 0.192308 0.192308  0.26923
## Q11    13    13         13 0.7436 0.6923   0.05128 0.113960 0.101140  0.20085
## Q12    13    13         13 0.6538 0.4423   0.21154 0.068109 0.084936  0.10256
## Q13    13    13         13 0.6923 0.6154   0.07692 0.230769 0.256410  0.41026
## Q14    13    13         13 0.6154 0.6154   0.00000 0.256410 0.256410  0.16667
## Q15    13    13         13 0.7385 0.6462   0.09231 0.102564 0.134359  0.08410
## Q16    13    13         13 0.9872 0.9872   0.00000 0.002137 0.002137  0.00000
## Q17    13    13         13 1.0000 0.9231   0.07692 0.000000 0.025997  0.02600
## Q18    13    13         13 0.8077 0.8077   0.00000 0.022436 0.022436  0.05208
##      stderr df statistic   pvalue conf.low conf.high mean.null alternative
## Q1  0.06708 12    1.7201 0.111065 -0.03077   0.26154         0   two.sided
## Q2  0.12463 12    3.3947 0.005322  0.15153   0.69462         0   two.sided
## Q3  0.05292 12    4.0698 0.001554  0.10008   0.33069         0   two.sided
## Q4  0.13282 12   -0.7722 0.454943 -0.39196   0.18683         0   two.sided
## Q5  0.14664 12    0.7868 0.446640 -0.20413   0.43489         0   two.sided
## Q6  0.08108 12    1.8974 0.082097 -0.02282   0.33051         0   two.sided
## Q7  0.16617 12    1.3887 0.190151 -0.13129   0.59283         0   two.sided
## Q8  0.08758 12   -1.1711 0.264296 -0.29339   0.08826         0   two.sided
## Q9  0.11323 12    0.0000 1.000000 -0.24670   0.24670         0   two.sided
## Q10 0.14391 12    3.7417 0.002813  0.22491   0.85201         0   two.sided
## Q11 0.12430 12    0.4126 0.687198 -0.21954   0.32211         0   two.sided
## Q12 0.08882 12    2.3816 0.034664  0.01801   0.40507         0   two.sided
## Q13 0.17765 12    0.4330 0.672686 -0.31013   0.46398         0   two.sided
## Q14 0.11323 12    0.0000 1.000000 -0.24670   0.24670         0   two.sided
## Q15 0.08043 12    1.1476 0.273484 -0.08294   0.26756         0   two.sided
## Q16      NA NA        NA       NA       NA        NA         0   two.sided
## Q17 0.04472 12    1.7201 0.111065 -0.02051   0.17436         0   two.sided
## Q18 0.06330 12    0.0000 1.000000 -0.13791   0.13791         0   two.sided
##     conf.level
## Q1        0.95
## Q2        0.95
## Q3        0.95
## Q4        0.95
## Q5        0.95
## Q6        0.95
## Q7        0.95
## Q8        0.95
## Q9        0.95
## Q10       0.95
## Q11       0.95
## Q12       0.95
## Q13       0.95
## Q14       0.95
## Q15       0.95
## Q16       0.95
## Q17       0.95
## Q18       0.95
```

```r
# Pull out with p  0.05 to identify questions with
# significant changes in score
questions_sig_diff <- questions_all_summary %>%
    filter(pvalue <= 0.05)
questions_sig_diff
```

```
##     obs.x obs.y obs.paired mean.x mean.y mean.diff   var.x   var.y var.diff
## Q2     13    13         13 0.8077 0.3846    0.4231 0.14744 0.21474  0.20192
## Q3     13    13         13 0.9231 0.7077    0.2154 0.01692 0.06410  0.03641
## Q10    13    13         13 0.7692 0.2308    0.5385 0.19231 0.19231  0.26923
## Q12    13    13         13 0.6538 0.4423    0.2115 0.06811 0.08494  0.10256
##      stderr df statistic   pvalue conf.low conf.high mean.null alternative
## Q2  0.12463 12     3.395 0.005322  0.15153    0.6946         0   two.sided
## Q3  0.05292 12     4.070 0.001554  0.10008    0.3307         0   two.sided
## Q10 0.14391 12     3.742 0.002813  0.22491    0.8520         0   two.sided
## Q12 0.08882 12     2.382 0.034664  0.01801    0.4051         0   two.sided
##     conf.level
## Q2        0.95
## Q3        0.95
## Q10       0.95
## Q12       0.95
```

```r
# Plot the questions by each answer by each student
library(ggplot2)
questions_data <- data.frame(questions_pre$Score, questions_post$Score)

question_avg <- data.frame(pre = c(questions_pre$Score), post = c(questions_post$Score))
question_avg$avg <- rowMeans(question_avg)
question_avg$diff <- question_avg$post - question_avg$pre
question_avg
```

```
##        pre   post    avg    diff
## 1   0.5000 0.5000 0.5000  0.0000
## 2   0.0000 0.5000 0.2500  0.5000
## 3   1.0000 1.0000 1.0000  0.0000
## 4   1.0000 0.6667 0.8333 -0.3333
## 5   1.0000 1.0000 1.0000  0.0000
## 6   1.0000 1.0000 1.0000  0.0000
## 7   1.0000 1.0000 1.0000  0.0000
## 8   0.6667 0.6667 0.6667  0.0000
## 9   1.0000 1.0000 1.0000  0.0000
## 10  1.0000 1.0000 1.0000  0.0000
## 11  0.3333 1.0000 0.6667  0.6667
## 12  0.7500 0.5000 0.6250 -0.2500
## 13  0.0000 1.0000 0.5000  1.0000
## 14  1.0000 1.0000 1.0000  0.0000
## 15  1.0000 1.0000 1.0000  0.0000
## 16  1.0000 1.0000 1.0000  0.0000
## 17  1.0000 1.0000 1.0000  0.0000
## 18  0.7500 1.0000 0.8750  0.2500
## 19  1.0000 0.7500 0.8750 -0.2500
## 20  0.0000 1.0000 0.5000  1.0000
## 21  0.4000 0.8000 0.6000  0.4000
```

```
## 22  0.3333 0.3333 0.3333  0.0000
## 23  0.5000 0.6667 0.5833  0.1667
## 24  0.6667 0.6667 0.6667  0.0000
## 25  1.0000 1.0000 1.0000  0.0000
## 26  1.0000 1.0000 1.0000  0.0000
## 27  0.5000 0.5000 0.5000  0.0000
## 28  0.0000 1.0000 0.5000  1.0000
## 29  0.6667 0.0000 0.3333 -0.6667
## 30  0.5000 0.5000 0.5000  0.0000
## 31  1.0000 1.0000 1.0000  0.0000
## 32  1.0000 0.0000 0.5000 -1.0000
## 33  0.0000 0.2000 0.1000  0.2000
## 34  1.0000 1.0000 1.0000  0.0000
## 35  1.0000 1.0000 1.0000  0.0000
## 36  1.0000 0.7500 0.8750 -0.2500
## 37  0.2500 1.0000 0.6250  0.7500
## 38  0.0000 1.0000 0.5000  1.0000
## 39  0.6000 1.0000 0.8000  0.4000
## 40  0.0000 1.0000 0.5000  1.0000
## 41  0.1667 1.0000 0.5833  0.8333
## 42  0.6667 1.0000 0.8333  0.3333
## 43  1.0000 1.0000 1.0000  0.0000
## 44  0.3333 0.3333 0.3333  0.0000
## 45  1.0000 1.0000 1.0000  0.0000
## 46  0.0000 1.0000 0.5000  1.0000
## 47  0.6667 1.0000 0.8333  0.3333
## 48  0.5000 1.0000 0.7500  0.5000
## 49  1.0000 1.0000 1.0000  0.0000
## 50  1.0000 1.0000 1.0000  0.0000
## 51  1.0000 1.0000 1.0000  0.0000
## 52  1.0000 1.0000 1.0000  0.0000
## 53  1.0000 1.0000 1.0000  0.0000
## 54  0.7500 1.0000 0.8750  0.2500
## 55  1.0000 1.0000 1.0000  0.0000
## 56  1.0000 1.0000 1.0000  0.0000
## 57  0.8000 1.0000 0.9000  0.2000
## 58  1.0000 0.6667 0.8333 -0.3333
## 59  0.1667 1.0000 0.5833  0.8333
## 60  1.0000 1.0000 1.0000  0.0000
## 61  1.0000 1.0000 1.0000  0.0000
## 62  1.0000 1.0000 1.0000  0.0000
## 63  0.5000 0.5000 0.5000  0.0000
## 64  1.0000 1.0000 1.0000  0.0000
## 65  1.0000 0.3333 0.6667 -0.6667
## 66  0.0000 0.7500 0.3750  0.7500
## 67  1.0000 1.0000 1.0000  0.0000
## 68  0.0000 1.0000 0.5000  1.0000
## 69  0.4000 1.0000 0.7000  0.6000
## 70  1.0000 1.0000 1.0000  0.0000
## 71  0.6667 1.0000 0.8333  0.3333
## 72  1.0000 0.7500 0.8750 -0.2500
## 73  0.7500 0.7500 0.7500  0.0000
## 74  1.0000 1.0000 1.0000  0.0000
## 75  0.6000 0.8000 0.7000  0.2000
```

```
## 76  0.3333 0.3333 0.3333  0.0000
## 77  0.5000 1.0000 0.7500  0.5000
## 78  0.6667 0.6667 0.6667  0.0000
## 79  1.0000 1.0000 1.0000  0.0000
## 80  1.0000 0.3333 0.6667 -0.6667
## 81  0.5000 0.5000 0.5000  0.0000
## 82  0.0000 1.0000 0.5000  1.0000
## 83  0.6667 1.0000 0.8333  0.3333
## 84  0.5000 0.5000 0.5000  0.0000
## 85  1.0000 1.0000 1.0000  0.0000
## 86  1.0000 1.0000 1.0000  0.0000
## 87  0.4000 0.4000 0.4000  0.0000
## 88  1.0000 1.0000 1.0000  0.0000
## 89  0.8333 1.0000 0.9167  0.1667
## 90  0.7500 0.7500 0.7500  0.0000
## 91  0.2500 0.5000 0.3750  0.2500
## 92  0.0000 1.0000 0.5000  1.0000
## 93  0.4000 1.0000 0.7000  0.6000
## 94  0.6667 0.6667 0.6667  0.0000
## 95  1.0000 0.0000 0.5000 -1.0000
## 96  0.3333 0.6667 0.5000  0.3333
## 97  1.0000 0.0000 0.5000 -1.0000
## 98  0.6667 0.6667 0.6667  0.0000
## 99  0.5000 0.5000 0.5000  0.0000
## 100 0.0000 0.0000 0.0000  0.0000
## 101 0.3333 0.3333 0.3333  0.0000
## 102 0.2500 0.2500 0.2500  0.0000
## 103 0.0000 0.0000 0.0000  0.0000
## 104 0.0000 0.0000 0.0000  0.0000
## 105 0.4000 0.2000 0.3000 -0.2000
## 106 1.0000 1.0000 1.0000  0.0000
## 107 1.0000 1.0000 1.0000  0.0000
## 108 0.7500 0.7500 0.7500  0.0000
## 109 1.0000 1.0000 1.0000  0.0000
## 110 0.5000 1.0000 0.7500  0.5000
## 111 1.0000 1.0000 1.0000  0.0000
## 112 1.0000 1.0000 1.0000  0.0000
## 113 1.0000 1.0000 1.0000  0.0000
## 114 1.0000 1.0000 1.0000  0.0000
## 115 1.0000 1.0000 1.0000  0.0000
## 116 0.3333 0.0000 0.1667 -0.3333
## 117 1.0000 1.0000 1.0000  0.0000
## 118 1.0000 1.0000 1.0000  0.0000
## 119 1.0000 1.0000 1.0000  0.0000
## 120 1.0000 1.0000 1.0000  0.0000
## 121 1.0000 1.0000 1.0000  0.0000
## 122 1.0000 1.0000 1.0000  0.0000
## 123 0.6000 0.6000 0.6000  0.0000
## 124 1.0000 1.0000 1.0000  0.0000
## 125 1.0000 1.0000 1.0000  0.0000
## 126 0.7500 1.0000 0.8750  0.2500
## 127 1.0000 1.0000 1.0000  0.0000
## 128 1.0000 1.0000 1.0000  0.0000
## 129 0.4000 0.8000 0.6000  0.4000
```

```
## 130 0.6667 0.6667 0.6667  0.0000
## 131 1.0000 0.8333 0.9167 -0.1667
## 132 0.3333 1.0000 0.6667  0.6667
## 133 0.0000 1.0000 0.5000  1.0000
## 134 1.0000 0.6667 0.8333 -0.3333
## 135 1.0000 0.5000 0.7500 -0.5000
## 136 0.0000 0.0000 0.0000  0.0000
## 137 0.6667 1.0000 0.8333  0.3333
## 138 0.7500 1.0000 0.8750  0.2500
## 139 0.0000 1.0000 0.5000  1.0000
## 140 1.0000 1.0000 1.0000  0.0000
## 141 1.0000 1.0000 1.0000  0.0000
## 142 1.0000 1.0000 1.0000  0.0000
## 143 1.0000 1.0000 1.0000  0.0000
## 144 0.7500 0.7500 0.7500  0.0000
## 145 1.0000 1.0000 1.0000  0.0000
## 146 0.5000 1.0000 0.7500  0.5000
## 147 0.8000 1.0000 0.9000  0.2000
## 148 0.3333 0.6667 0.5000  0.3333
## 149 1.0000 1.0000 1.0000  0.0000
## 150 0.6667 1.0000 0.8333  0.3333
## 151 0.0000 1.0000 0.5000  1.0000
## 152 1.0000 1.0000 1.0000  0.0000
## 153 0.5000 1.0000 0.7500  0.5000
## 154 0.0000 1.0000 0.5000  1.0000
## 155 1.0000 1.0000 1.0000  0.0000
## 156 0.2500 1.0000 0.6250  0.7500
## 157 0.0000 1.0000 0.5000  1.0000
## 158 1.0000 1.0000 1.0000  0.0000
## 159 1.0000 1.0000 1.0000  0.0000
## 160 1.0000 1.0000 1.0000  0.0000
## 161 1.0000 1.0000 1.0000  0.0000
## 162 0.5000 0.7500 0.6250  0.2500
## 163 0.5000 0.7500 0.6250  0.2500
## 164 0.0000 1.0000 0.5000  1.0000
## 165 0.8000 1.0000 0.9000  0.2000
## 166 0.3333 0.0000 0.1667 -0.3333
## 167 0.5000 0.3333 0.4167 -0.1667
## 168 0.3333 1.0000 0.6667  0.6667
## 169 0.0000 0.0000 0.0000  0.0000
## 170 0.6667 1.0000 0.8333  0.3333
## 171 1.0000 1.0000 1.0000  0.0000
## 172 0.0000 0.0000 0.0000  0.0000
## 173 0.6667 1.0000 0.8333  0.3333
## 174 0.0000 0.5000 0.2500  0.5000
## 175 1.0000 0.0000 0.5000 -1.0000
## 176 0.0000 0.0000 0.0000  0.0000
## 177 0.4000 1.0000 0.7000  0.6000
## 178 0.8333 0.8333 0.8333  0.0000
## 179 0.5000 1.0000 0.7500  0.5000
## 180 1.0000 0.7500 0.8750 -0.2500
## 181 1.0000 1.0000 1.0000  0.0000
## 182 1.0000 1.0000 1.0000  0.0000
## 183 1.0000 1.0000 1.0000  0.0000
```

```
## 184 1.0000 0.3333 0.6667 -0.6667
## 185 0.1667 1.0000 0.5833  0.8333
## 186 1.0000 1.0000 1.0000  0.0000
## 187 1.0000 1.0000 1.0000  0.0000
## 188 1.0000 1.0000 1.0000  0.0000
## 189 1.0000 0.5000 0.7500 -0.5000
## 190 0.0000 1.0000 0.5000  1.0000
## 191 1.0000 0.6667 0.8333 -0.3333
## 192 0.5000 0.5000 0.5000  0.0000
## 193 1.0000 1.0000 1.0000  0.0000
## 194 0.0000 0.0000 0.0000  0.0000
## 195 1.0000 1.0000 1.0000  0.0000
## 196 1.0000 1.0000 1.0000  0.0000
## 197 1.0000 1.0000 1.0000  0.0000
## 198 0.7500 1.0000 0.8750  0.2500
## 199 0.2500 0.5000 0.3750  0.2500
## 200 0.0000 0.0000 0.0000  0.0000
## 201 0.4000 0.6000 0.5000  0.2000
## 202 0.6667 0.6667 0.6667  0.0000
## 203 0.5000 0.1667 0.3333 -0.3333
## 204 0.6667 0.3333 0.5000 -0.3333
## 205 0.0000 1.0000 0.5000  1.0000
## 206 0.6667 1.0000 0.8333  0.3333
## 207 0.0000 1.0000 0.5000  1.0000
## 208 0.0000 1.0000 0.5000  1.0000
## 209 0.0000 0.6667 0.3333  0.6667
## 210 0.5000 0.5000 0.5000  0.0000
## 211 1.0000 0.0000 0.5000 -1.0000
## 212 0.0000 0.0000 0.0000  0.0000
## 213 1.0000 0.6000 0.8000 -0.4000
## 214 1.0000 1.0000 1.0000  0.0000
## 215 1.0000 1.0000 1.0000  0.0000
## 216 0.7500 0.5000 0.6250 -0.2500
## 217 0.5000 0.7500 0.6250  0.2500
## 218 0.0000 0.0000 0.0000  0.0000
## 219 1.0000 1.0000 1.0000  0.0000
## 220 1.0000 0.0000 0.5000 -1.0000
## 221 1.0000 1.0000 1.0000  0.0000
## 222 0.6667 0.6667 0.6667  0.0000
## 223 0.0000 1.0000 0.5000  1.0000
## 224 1.0000 0.3333 0.6667 -0.6667
## 225 1.0000 0.5000 0.7500 -0.5000
## 226 0.0000 1.0000 0.5000  1.0000
## 227 1.0000 0.6667 0.8333 -0.3333
## 228 0.2500 0.5000 0.3750  0.2500
## 229 0.0000 0.0000 0.0000  0.0000
## 230 1.0000 1.0000 1.0000  0.0000
## 231 0.2000 0.6000 0.4000  0.4000
## 232 1.0000 1.0000 1.0000  0.0000
## 233 1.0000 1.0000 1.0000  0.0000
## 234 1.0000 0.7500 0.8750 -0.2500
```

```
question_avg$question <- questions_pre$Question
question_avg
```

```
##        pre   post    avg    diff question
## 1   0.5000 0.5000 0.5000  0.0000       Q1
## 2   0.0000 0.5000 0.2500  0.5000       Q2
## 3   1.0000 1.0000 1.0000  0.0000       Q3
## 4   1.0000 0.6667 0.8333 -0.3333       Q4
## 5   1.0000 1.0000 1.0000  0.0000       Q5
## 6   1.0000 1.0000 1.0000  0.0000       Q6
## 7   1.0000 1.0000 1.0000  0.0000       Q7
## 8   0.6667 0.6667 0.6667  0.0000       Q8
## 9   1.0000 1.0000 1.0000  0.0000       Q9
## 10  1.0000 1.0000 1.0000  0.0000      Q10
## 11  0.3333 1.0000 0.6667  0.6667      Q11
## 12  0.7500 0.5000 0.6250 -0.2500      Q12
## 13  0.0000 1.0000 0.5000  1.0000      Q13
## 14  1.0000 1.0000 1.0000  0.0000      Q14
## 15  1.0000 1.0000 1.0000  0.0000      Q15
## 16  1.0000 1.0000 1.0000  0.0000      Q16
## 17  1.0000 1.0000 1.0000  0.0000      Q17
## 18  0.7500 1.0000 0.8750  0.2500      Q18
## 19  1.0000 0.7500 0.8750 -0.2500       Q1
## 20  0.0000 1.0000 0.5000  1.0000       Q2
## 21  0.4000 0.8000 0.6000  0.4000       Q3
## 22  0.3333 0.3333 0.3333  0.0000       Q4
## 23  0.5000 0.6667 0.5833  0.1667       Q5
## 24  0.6667 0.6667 0.6667  0.0000       Q6
## 25  1.0000 1.0000 1.0000  0.0000       Q7
## 26  1.0000 1.0000 1.0000  0.0000       Q8
## 27  0.5000 0.5000 0.5000  0.0000       Q9
## 28  0.0000 1.0000 0.5000  1.0000      Q10
## 29  0.6667 0.0000 0.3333 -0.6667      Q11
## 30  0.5000 0.5000 0.5000  0.0000      Q12
## 31  1.0000 1.0000 1.0000  0.0000      Q13
## 32  1.0000 0.0000 0.5000 -1.0000      Q14
## 33  0.0000 0.2000 0.1000  0.2000      Q15
## 34  1.0000 1.0000 1.0000  0.0000      Q16
## 35  1.0000 1.0000 1.0000  0.0000      Q17
## 36  1.0000 0.7500 0.8750 -0.2500      Q18
## 37  0.2500 1.0000 0.6250  0.7500       Q1
## 38  0.0000 1.0000 0.5000  1.0000       Q2
## 39  0.6000 1.0000 0.8000  0.4000       Q3
## 40  0.0000 1.0000 0.5000  1.0000       Q4
## 41  0.1667 1.0000 0.5833  0.8333       Q5
## 42  0.6667 1.0000 0.8333  0.3333       Q6
## 43  1.0000 1.0000 1.0000  0.0000       Q7
## 44  0.3333 0.3333 0.3333  0.0000       Q8
## 45  1.0000 1.0000 1.0000  0.0000       Q9
## 46  0.0000 1.0000 0.5000  1.0000      Q10
## 47  0.6667 1.0000 0.8333  0.3333      Q11
## 48  0.5000 1.0000 0.7500  0.5000      Q12
## 49  1.0000 1.0000 1.0000  0.0000      Q13
## 50  1.0000 1.0000 1.0000  0.0000      Q14
## 51  1.0000 1.0000 1.0000  0.0000      Q15
## 52  1.0000 1.0000 1.0000  0.0000      Q16
## 53  1.0000 1.0000 1.0000  0.0000      Q17
```

```
## 54  0.7500 1.0000 0.8750  0.2500      Q18
## 55  1.0000 1.0000 1.0000  0.0000       Q1
## 56  1.0000 1.0000 1.0000  0.0000       Q2
## 57  0.8000 1.0000 0.9000  0.2000       Q3
## 58  1.0000 0.6667 0.8333 -0.3333       Q4
## 59  0.1667 1.0000 0.5833  0.8333       Q5
## 60  1.0000 1.0000 1.0000  0.0000       Q6
## 61  1.0000 1.0000 1.0000  0.0000       Q7
## 62  1.0000 1.0000 1.0000  0.0000       Q8
## 63  0.5000 0.5000 0.5000  0.0000       Q9
## 64  1.0000 1.0000 1.0000  0.0000      Q10
## 65  1.0000 0.3333 0.6667 -0.6667      Q11
## 66  0.0000 0.7500 0.3750  0.7500      Q12
## 67  1.0000 1.0000 1.0000  0.0000      Q13
## 68  0.0000 1.0000 0.5000  1.0000      Q14
## 69  0.4000 1.0000 0.7000  0.6000      Q15
## 70  1.0000 1.0000 1.0000  0.0000      Q16
## 71  0.6667 1.0000 0.8333  0.3333      Q17
## 72  1.0000 0.7500 0.8750 -0.2500      Q18
## 73  0.7500 0.7500 0.7500  0.0000       Q1
## 74  1.0000 1.0000 1.0000  0.0000       Q2
## 75  0.6000 0.8000 0.7000  0.2000       Q3
## 76  0.3333 0.3333 0.3333  0.0000       Q4
## 77  0.5000 1.0000 0.7500  0.5000       Q5
## 78  0.6667 0.6667 0.6667  0.0000       Q6
## 79  1.0000 1.0000 1.0000  0.0000       Q7
## 80  1.0000 0.3333 0.6667 -0.6667       Q8
## 81  0.5000 0.5000 0.5000  0.0000       Q9
## 82  0.0000 1.0000 0.5000  1.0000      Q10
## 83  0.6667 1.0000 0.8333  0.3333      Q11
## 84  0.5000 0.5000 0.5000  0.0000      Q12
## 85  1.0000 1.0000 1.0000  0.0000      Q13
## 86  1.0000 1.0000 1.0000  0.0000      Q14
## 87  0.4000 0.4000 0.4000  0.0000      Q15
## 88  1.0000 1.0000 1.0000  0.0000      Q16
## 89  0.8333 1.0000 0.9167  0.1667      Q17
## 90  0.7500 0.7500 0.7500  0.0000      Q18
## 91  0.2500 0.5000 0.3750  0.2500       Q1
## 92  0.0000 1.0000 0.5000  1.0000       Q2
## 93  0.4000 1.0000 0.7000  0.6000       Q3
## 94  0.6667 0.6667 0.6667  0.0000       Q4
## 95  1.0000 0.0000 0.5000 -1.0000       Q5
## 96  0.3333 0.6667 0.5000  0.3333       Q6
## 97  1.0000 0.0000 0.5000 -1.0000       Q7
## 98  0.6667 0.6667 0.6667  0.0000       Q8
## 99  0.5000 0.5000 0.5000  0.0000       Q9
## 100 0.0000 0.0000 0.0000  0.0000      Q10
## 101 0.3333 0.3333 0.3333  0.0000      Q11
## 102 0.2500 0.2500 0.2500  0.0000      Q12
## 103 0.0000 0.0000 0.0000  0.0000      Q13
## 104 0.0000 0.0000 0.0000  0.0000      Q14
## 105 0.4000 0.2000 0.3000 -0.2000      Q15
## 106 1.0000 1.0000 1.0000  0.0000      Q16
## 107 1.0000 1.0000 1.0000  0.0000      Q17
```

```
## 108 0.7500 0.7500 0.7500  0.0000      Q18
## 109 1.0000 1.0000 1.0000  0.0000       Q1
## 110 0.5000 1.0000 0.7500  0.5000       Q2
## 111 1.0000 1.0000 1.0000  0.0000       Q3
## 112 1.0000 1.0000 1.0000  0.0000       Q4
## 113 1.0000 1.0000 1.0000  0.0000       Q5
## 114 1.0000 1.0000 1.0000  0.0000       Q6
## 115 1.0000 1.0000 1.0000  0.0000       Q7
## 116 0.3333 0.0000 0.1667 -0.3333       Q8
## 117 1.0000 1.0000 1.0000  0.0000       Q9
## 118 1.0000 1.0000 1.0000  0.0000      Q10
## 119 1.0000 1.0000 1.0000  0.0000      Q11
## 120 1.0000 1.0000 1.0000  0.0000      Q12
## 121 1.0000 1.0000 1.0000  0.0000      Q13
## 122 1.0000 1.0000 1.0000  0.0000      Q14
## 123 0.6000 0.6000 0.6000  0.0000      Q15
## 124 1.0000 1.0000 1.0000  0.0000      Q16
## 125 1.0000 1.0000 1.0000  0.0000      Q17
## 126 0.7500 1.0000 0.8750  0.2500      Q18
## 127 1.0000 1.0000 1.0000  0.0000       Q1
## 128 1.0000 1.0000 1.0000  0.0000       Q2
## 129 0.4000 0.8000 0.6000  0.4000       Q3
## 130 0.6667 0.6667 0.6667  0.0000       Q4
## 131 1.0000 0.8333 0.9167 -0.1667       Q5
## 132 0.3333 1.0000 0.6667  0.6667       Q6
## 133 0.0000 1.0000 0.5000  1.0000       Q7
## 134 1.0000 0.6667 0.8333 -0.3333       Q8
## 135 1.0000 0.5000 0.7500 -0.5000       Q9
## 136 0.0000 0.0000 0.0000  0.0000      Q10
## 137 0.6667 1.0000 0.8333  0.3333      Q11
## 138 0.7500 1.0000 0.8750  0.2500      Q12
## 139 0.0000 1.0000 0.5000  1.0000      Q13
## 140 1.0000 1.0000 1.0000  0.0000      Q14
## 141 1.0000 1.0000 1.0000  0.0000      Q15
## 142 1.0000 1.0000 1.0000  0.0000      Q16
## 143 1.0000 1.0000 1.0000  0.0000      Q17
## 144 0.7500 0.7500 0.7500  0.0000      Q18
## 145 1.0000 1.0000 1.0000  0.0000       Q1
## 146 0.5000 1.0000 0.7500  0.5000       Q2
## 147 0.8000 1.0000 0.9000  0.2000       Q3
## 148 0.3333 0.6667 0.5000  0.3333       Q4
## 149 1.0000 1.0000 1.0000  0.0000       Q5
## 150 0.6667 1.0000 0.8333  0.3333       Q6
## 151 0.0000 1.0000 0.5000  1.0000       Q7
## 152 1.0000 1.0000 1.0000  0.0000       Q8
## 153 0.5000 1.0000 0.7500  0.5000       Q9
## 154 0.0000 1.0000 0.5000  1.0000      Q10
## 155 1.0000 1.0000 1.0000  0.0000      Q11
## 156 0.2500 1.0000 0.6250  0.7500      Q12
## 157 0.0000 1.0000 0.5000  1.0000      Q13
## 158 1.0000 1.0000 1.0000  0.0000      Q14
## 159 1.0000 1.0000 1.0000  0.0000      Q15
## 160 1.0000 1.0000 1.0000  0.0000      Q16
## 161 1.0000 1.0000 1.0000  0.0000      Q17
```

```
## 162 0.5000 0.7500 0.6250  0.2500      Q18
## 163 0.5000 0.7500 0.6250  0.2500       Q1
## 164 0.0000 1.0000 0.5000  1.0000       Q2
## 165 0.8000 1.0000 0.9000  0.2000       Q3
## 166 0.3333 0.0000 0.1667 -0.3333       Q4
## 167 0.5000 0.3333 0.4167 -0.1667       Q5
## 168 0.3333 1.0000 0.6667  0.6667       Q6
## 169 0.0000 0.0000 0.0000  0.0000       Q7
## 170 0.6667 1.0000 0.8333  0.3333       Q8
## 171 1.0000 1.0000 1.0000  0.0000       Q9
## 172 0.0000 0.0000 0.0000  0.0000      Q10
## 173 0.6667 1.0000 0.8333  0.3333      Q11
## 174 0.0000 0.5000 0.2500  0.5000      Q12
## 175 1.0000 0.0000 0.5000 -1.0000      Q13
## 176 0.0000 0.0000 0.0000  0.0000      Q14
## 177 0.4000 1.0000 0.7000  0.6000      Q15
## 178 0.8333 0.8333 0.8333  0.0000      Q16
## 179 0.5000 1.0000 0.7500  0.5000      Q17
## 180 1.0000 0.7500 0.8750 -0.2500      Q18
## 181 1.0000 1.0000 1.0000  0.0000       Q1
## 182 1.0000 1.0000 1.0000  0.0000       Q2
## 183 1.0000 1.0000 1.0000  0.0000       Q3
## 184 1.0000 0.3333 0.6667 -0.6667       Q4
## 185 0.1667 1.0000 0.5833  0.8333       Q5
## 186 1.0000 1.0000 1.0000  0.0000       Q6
## 187 1.0000 1.0000 1.0000  0.0000       Q7
## 188 1.0000 1.0000 1.0000  0.0000       Q8
## 189 1.0000 0.5000 0.7500 -0.5000       Q9
## 190 0.0000 1.0000 0.5000  1.0000      Q10
## 191 1.0000 0.6667 0.8333 -0.3333      Q11
## 192 0.5000 0.5000 0.5000  0.0000      Q12
## 193 1.0000 1.0000 1.0000  0.0000      Q13
## 194 0.0000 0.0000 0.0000  0.0000      Q14
## 195 1.0000 1.0000 1.0000  0.0000      Q15
## 196 1.0000 1.0000 1.0000  0.0000      Q16
## 197 1.0000 1.0000 1.0000  0.0000      Q17
## 198 0.7500 1.0000 0.8750  0.2500      Q18
## 199 0.2500 0.5000 0.3750  0.2500       Q1
## 200 0.0000 0.0000 0.0000  0.0000       Q2
## 201 0.4000 0.6000 0.5000  0.2000       Q3
## 202 0.6667 0.6667 0.6667  0.0000       Q4
## 203 0.5000 0.1667 0.3333 -0.3333       Q5
## 204 0.6667 0.3333 0.5000 -0.3333       Q6
## 205 0.0000 1.0000 0.5000  1.0000       Q7
## 206 0.6667 1.0000 0.8333  0.3333       Q8
## 207 0.0000 1.0000 0.5000  1.0000       Q9
## 208 0.0000 1.0000 0.5000  1.0000      Q10
## 209 0.0000 0.6667 0.3333  0.6667      Q11
## 210 0.5000 0.5000 0.5000  0.0000      Q12
## 211 1.0000 0.0000 0.5000 -1.0000      Q13
## 212 0.0000 0.0000 0.0000  0.0000      Q14
## 213 1.0000 0.6000 0.8000 -0.4000      Q15
## 214 1.0000 1.0000 1.0000  0.0000      Q16
## 215 1.0000 1.0000 1.0000  0.0000      Q17
```

```
## 216 0.7500 0.5000 0.6250 -0.2500      Q18
## 217 0.5000 0.7500 0.6250  0.2500       Q1
## 218 0.0000 0.0000 0.0000  0.0000       Q2
## 219 1.0000 1.0000 1.0000  0.0000       Q3
## 220 1.0000 0.0000 0.5000 -1.0000       Q4
## 221 1.0000 1.0000 1.0000  0.0000       Q5
## 222 0.6667 0.6667 0.6667  0.0000       Q6
## 223 0.0000 1.0000 0.5000  1.0000       Q7
## 224 1.0000 0.3333 0.6667 -0.6667       Q8
## 225 1.0000 0.5000 0.7500 -0.5000       Q9
## 226 0.0000 1.0000 0.5000  1.0000      Q10
## 227 1.0000 0.6667 0.8333 -0.3333      Q11
## 228 0.2500 0.5000 0.3750  0.2500      Q12
## 229 0.0000 0.0000 0.0000  0.0000      Q13
## 230 1.0000 1.0000 1.0000  0.0000      Q14
## 231 0.2000 0.6000 0.4000  0.4000      Q15
## 232 1.0000 1.0000 1.0000  0.0000      Q16
## 233 1.0000 1.0000 1.0000  0.0000      Q17
## 234 1.0000 0.7500 0.8750 -0.2500      Q18
```

```
# find average difference
question_mean_diff <- mean(question_avg$diff)
question_mean_diff
```

```
## [1] 0.1165
```

```
# find lower and upper 95% confidence interval limits
questions_lower <- question_mean_diff - 1.96 * sd(question_avg$diff)

questions_upper <- question_mean_diff + 1.96 * sd(question_avg$diff)

print(questions_lower)
```

```
## [1] -0.6953
```

```
print(questions_upper)
```

```
## [1] 0.9282
```

```
# Test for normality
shapiro.test(questions_pre$Score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  questions_pre$Score
## W = 0.8, p-value <2e-16
```

```
shapiro.test(questions_post$Score)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  questions_post$Score
## W = 0.71, p-value <2e-16
```

```
## Both p-values were < 0.05; use KS paired test
ks <- ks.test(questions_pre$Score, questions_post$Score)
```

```
## Warning in ks.test.default(questions_pre$Score, questions_post$Score): p-value
## will be approximate in the presence of ties
```

```
## P-value still accepting the null, non-normal
## distribution Try Wilcoxon test
wt_questions <- wilcox.test(question_avg$post, question_avg$pre)

stat.test <- wilcox.test(question_avg$pre, question_avg$post)
stat.test
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  question_avg$pre and question_avg$post
## W = 22734, p-value = 6e-04
## alternative hypothesis: true location shift is not equal to 0
```

```
# Data for Bland-Altman plot Plot the questions by each
# question mean of all the students

question_avg_class <- data.frame(pre = c(qmu1_pre$grp.mean),
    post = c(qmu2_post$grp.mean))
question_avg_class$avg <- rowMeans(question_avg_class)
question_avg_class$diff <- question_avg_class$post - question_avg_class$pre
question_avg_class
```

```
##       pre   post    avg     diff
## 1  0.6923 0.8077 0.7500  0.11538
## 2  0.2308 0.7692 0.5000  0.53846
## 3  0.6923 0.7436 0.7179  0.05128
## 4  0.4423 0.6538 0.5481  0.21154
## 5  0.6154 0.6923 0.6538  0.07692
## 6  0.6154 0.6154 0.6154  0.00000
## 7  0.6462 0.7385 0.6923  0.09231
## 8  0.9872 0.9872 0.9872  0.00000
## 9  0.9231 1.0000 0.9615  0.07692
## 10 0.8077 0.8077 0.8077  0.00000
## 11 0.3846 0.8077 0.5962  0.42308
## 12 0.7077 0.9231 0.8154  0.21538
## 13 0.6410 0.5385 0.5897 -0.10256
## 14 0.6538 0.7692 0.7115  0.11538
## 15 0.6923 0.8462 0.7692  0.15385
## 16 0.6154 0.8462 0.7308  0.23077
## 17 0.7949 0.6923 0.7436 -0.10256
## 18 0.7308 0.7308 0.7308  0.00000
```

```r
# add questions back in
question_avg_class$question <- qmu1_pre$Question
question_avg_class
```

```
##       pre   post    avg     diff question
## 1  0.6923 0.8077 0.7500  0.11538       Q1
## 2  0.2308 0.7692 0.5000  0.53846      Q10
## 3  0.6923 0.7436 0.7179  0.05128      Q11
## 4  0.4423 0.6538 0.5481  0.21154      Q12
## 5  0.6154 0.6923 0.6538  0.07692      Q13
## 6  0.6154 0.6154 0.6154  0.00000      Q14
## 7  0.6462 0.7385 0.6923  0.09231      Q15
## 8  0.9872 0.9872 0.9872  0.00000      Q16
## 9  0.9231 1.0000 0.9615  0.07692      Q17
## 10 0.8077 0.8077 0.8077  0.00000      Q18
## 11 0.3846 0.8077 0.5962  0.42308       Q2
## 12 0.7077 0.9231 0.8154  0.21538       Q3
## 13 0.6410 0.5385 0.5897 -0.10256       Q4
## 14 0.6538 0.7692 0.7115  0.11538       Q5
## 15 0.6923 0.8462 0.7692  0.15385       Q6
## 16 0.6154 0.8462 0.7308  0.23077       Q7
## 17 0.7949 0.6923 0.7436 -0.10256       Q8
## 18 0.7308 0.7308 0.7308  0.00000       Q9
```

```r
# find average difference
question_mean_diff_class <- mean(question_avg_class$diff)
question_mean_diff_class
```

```
## [1] 0.1165
```

```r
# find lower and upper 95% confidence interval limits
questions_lower_class <- question_mean_diff_class - 1.96 * sd(question_avg_class$diff)

questions_upper_class <- question_mean_diff_class + 1.96 * sd(question_avg$diff)

print(questions_lower_class)
```

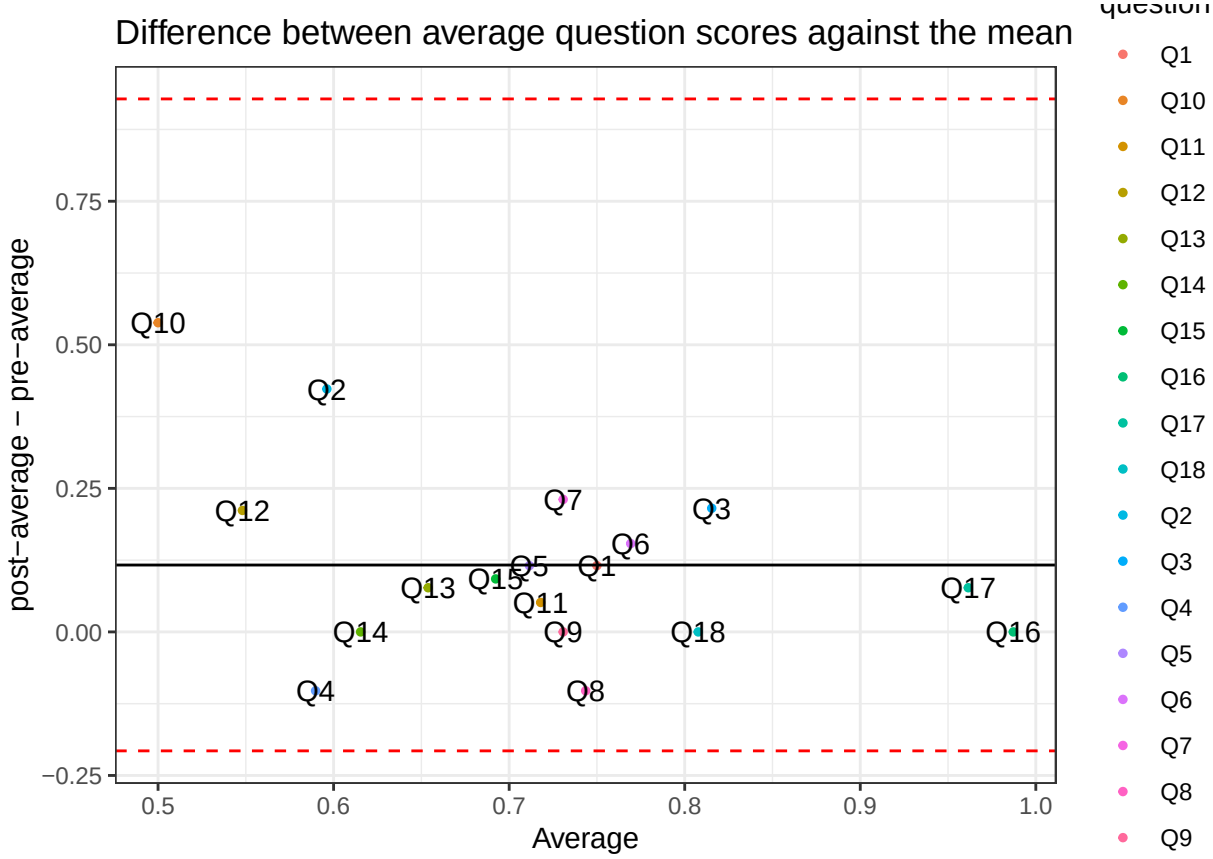
```
## [1] -0.2072
```

```r
print(questions_upper_class)
```

```
## [1] 0.9282
```

```r
# Plot Bland-Altman plot

q <- ggplot(question_avg_class, aes(x = avg, y = diff)) + geom_point(size = 1,
    aes(color = question)) + geom_hline(yintercept = question_mean_diff_class) +
    geom_hline(yintercept = questions_lower_class, color = "red",
        linetype = "dashed") + geom_hline(yintercept = questions_upper_class,
    color = "red", linetype = "dashed") + ggtitle("Difference between average question scores against t
```

```
    ylab("post-average - pre-average") + xlab("Average") + theme_bw()


q + geom_text(label = question_avg_class$question)
```



Normalized Learning Gain per question

NLG is the difference between post and pre scores divided by the difference between the maximum score possible and the pre-score.

[postscore - prescore]/[maximum score - prescore]

```
# Create a dataframe with pre and post mean scores per
# question Add back the question topic area
qmu_stats <- data.frame(pre_mean = qmu1_pre$grp.mean, post_mean = qmu2_post$grp.mean,
    topic = c("BIOLOGY", "CODING", "CODING", "CODING", "CODING",
        "CODING", "PROFDEV", "PROFDEV", "PROFDEV", "PROFDEV",
        "BIOLOGY", "BIOLOGY", "BIOLOGY", "BIOLOGY", "BIOLOGY",
        "BIOLOGY", "CODING", "CODING"))
qmu_stats
```

```
##    pre_mean post_mean   topic
## 1    0.6923    0.8077 BIOLOGY
## 2    0.2308    0.7692  CODING
```

```
## 3    0.6923    0.7436  CODING
## 4    0.4423    0.6538  CODING
## 5    0.6154    0.6923  CODING
## 6    0.6154    0.6154  CODING
## 7    0.6462    0.7385 PROFDEV
## 8    0.9872    0.9872 PROFDEV
## 9    0.9231    1.0000 PROFDEV
## 10   0.8077    0.8077 PROFDEV
## 11   0.3846    0.8077 BIOLOGY
## 12   0.7077    0.9231 BIOLOGY
## 13   0.6410    0.5385 BIOLOGY
## 14   0.6538    0.7692 BIOLOGY
## 15   0.6923    0.8462 BIOLOGY
## 16   0.6154    0.8462 BIOLOGY
## 17   0.7949    0.6923  CODING
## 18   0.7308    0.7308  CODING
```

```
# Calculate NLG Add a row to the subtract the average score
# from the maximum (1pt)
qmu_stats$from_max <- 1 - qmu_stats[, 1]
# Find the difference between the average post-score and
# pre-score of every question by subtracting column 1 from
# column 2
qmu_stats$diff <- qmu_stats[, 2] - qmu_stats[, 1]

# Divide the difference between pre and post scores by the
# maximum increase possible (100% - score)
qmu_stats$nlg <- qmu_stats[, 5]/qmu_stats[, 4]
qmu_stats
```

```
##    pre_mean post_mean   topic from_max     diff     nlg
## 1    0.6923    0.8077 BIOLOGY  0.30769  0.11538  0.3750
## 2    0.2308    0.7692  CODING  0.76923  0.53846  0.7000
## 3    0.6923    0.7436  CODING  0.30769  0.05128  0.1667
## 4    0.4423    0.6538  CODING  0.55769  0.21154  0.3793
## 5    0.6154    0.6923  CODING  0.38462  0.07692  0.2000
## 6    0.6154    0.6154  CODING  0.38462  0.00000  0.0000
## 7    0.6462    0.7385 PROFDEV  0.35385  0.09231  0.2609
## 8    0.9872    0.9872 PROFDEV  0.01282  0.00000  0.0000
## 9    0.9231    1.0000 PROFDEV  0.07692  0.07692  1.0000
## 10   0.8077    0.8077 PROFDEV  0.19231  0.00000  0.0000
## 11   0.3846    0.8077 BIOLOGY  0.61538  0.42308  0.6875
## 12   0.7077    0.9231 BIOLOGY  0.29231  0.21538  0.7368
## 13   0.6410    0.5385 BIOLOGY  0.35897 -0.10256 -0.2857
## 14   0.6538    0.7692 BIOLOGY  0.34615  0.11538  0.3333
## 15   0.6923    0.8462 BIOLOGY  0.30769  0.15385  0.5000
## 16   0.6154    0.8462 BIOLOGY  0.38462  0.23077  0.6000
## 17   0.7949    0.6923  CODING  0.20513 -0.10256 -0.5000
## 18   0.7308    0.7308  CODING  0.26923  0.00000  0.0000
```

```
# Add question labels back
qmu_stats$question <- qmu1_pre$Question
qmu_stats
```

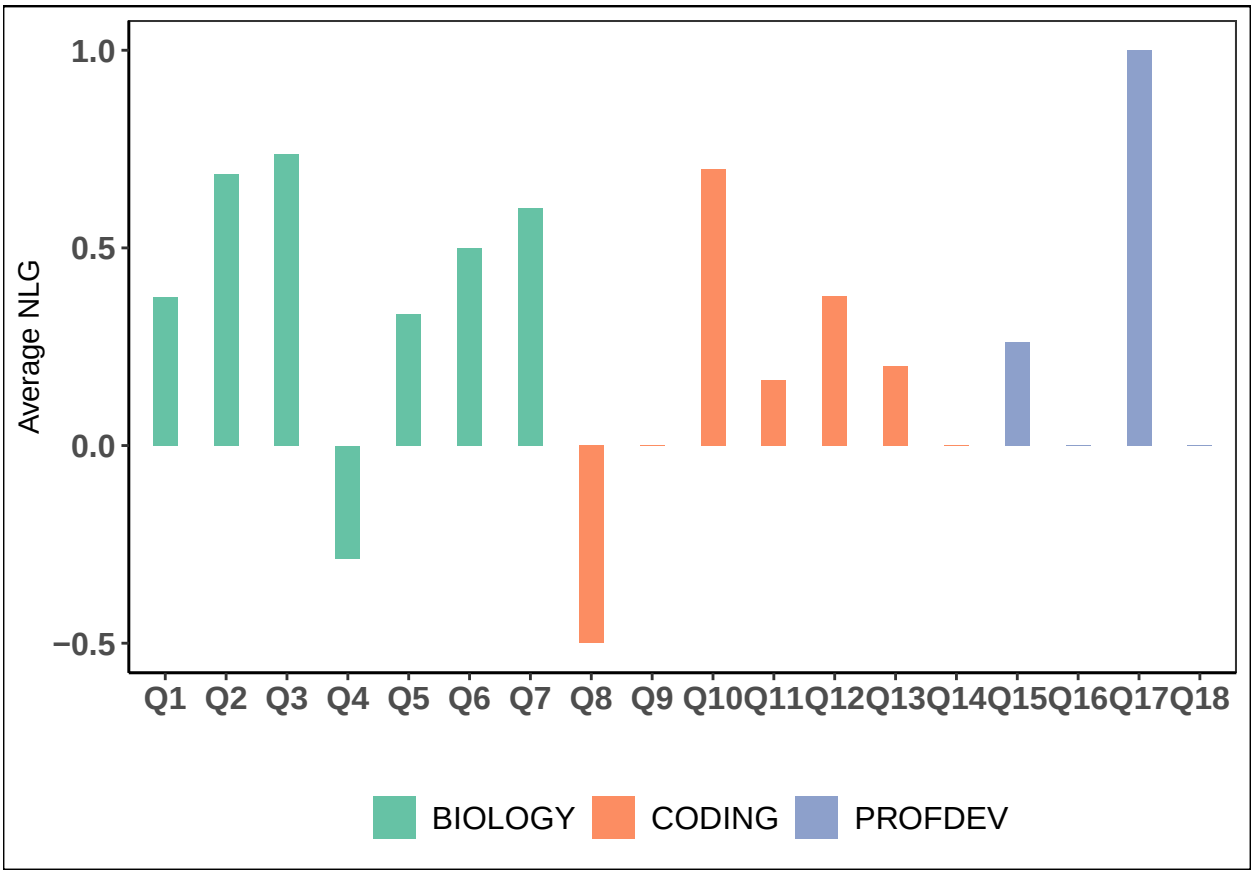
```
##    pre_mean post_mean   topic from_max     diff     nlg question
## 1    0.6923    0.8077 BIOLOGY  0.30769  0.11538  0.3750       Q1
## 2    0.2308    0.7692  CODING  0.76923  0.53846  0.7000      Q10
## 3    0.6923    0.7436  CODING  0.30769  0.05128  0.1667      Q11
## 4    0.4423    0.6538  CODING  0.55769  0.21154  0.3793      Q12
## 5    0.6154    0.6923  CODING  0.38462  0.07692  0.2000      Q13
## 6    0.6154    0.6154  CODING  0.38462  0.00000  0.0000      Q14
## 7    0.6462    0.7385 PROFDEV  0.35385  0.09231  0.2609      Q15
## 8    0.9872    0.9872 PROFDEV  0.01282  0.00000  0.0000      Q16
## 9    0.9231    1.0000 PROFDEV  0.07692  0.07692  1.0000      Q17
## 10   0.8077    0.8077 PROFDEV  0.19231  0.00000  0.0000      Q18
## 11   0.3846    0.8077 BIOLOGY  0.61538  0.42308  0.6875       Q2
## 12   0.7077    0.9231 BIOLOGY  0.29231  0.21538  0.7368       Q3
## 13   0.6410    0.5385 BIOLOGY  0.35897 -0.10256 -0.2857       Q4
## 14   0.6538    0.7692 BIOLOGY  0.34615  0.11538  0.3333       Q5
## 15   0.6923    0.8462 BIOLOGY  0.30769  0.15385  0.5000       Q6
## 16   0.6154    0.8462 BIOLOGY  0.38462  0.23077  0.6000       Q7
## 17   0.7949    0.6923  CODING  0.20513 -0.10256 -0.5000       Q8
## 18   0.7308    0.7308  CODING  0.26923  0.00000  0.0000       Q9
```

```
# set the order for the plot
qmu_stats$question <- factor(qmu_stats$question, levels = c("Q1",
    "Q2", "Q3", "Q4", "Q5", "Q6", "Q7", "Q8", "Q9", "Q10", "Q11",
    "Q12", "Q13", "Q14", "Q15", "Q16", "Q17", "Q18"))

# check the order
qmu_stats
```

```
##    pre_mean post_mean   topic from_max     diff     nlg question
## 1    0.6923    0.8077 BIOLOGY  0.30769  0.11538  0.3750       Q1
## 2    0.2308    0.7692  CODING  0.76923  0.53846  0.7000      Q10
## 3    0.6923    0.7436  CODING  0.30769  0.05128  0.1667      Q11
## 4    0.4423    0.6538  CODING  0.55769  0.21154  0.3793      Q12
## 5    0.6154    0.6923  CODING  0.38462  0.07692  0.2000      Q13
## 6    0.6154    0.6154  CODING  0.38462  0.00000  0.0000      Q14
## 7    0.6462    0.7385 PROFDEV  0.35385  0.09231  0.2609      Q15
## 8    0.9872    0.9872 PROFDEV  0.01282  0.00000  0.0000      Q16
## 9    0.9231    1.0000 PROFDEV  0.07692  0.07692  1.0000      Q17
## 10   0.8077    0.8077 PROFDEV  0.19231  0.00000  0.0000      Q18
## 11   0.3846    0.8077 BIOLOGY  0.61538  0.42308  0.6875       Q2
## 12   0.7077    0.9231 BIOLOGY  0.29231  0.21538  0.7368       Q3
## 13   0.6410    0.5385 BIOLOGY  0.35897 -0.10256 -0.2857       Q4
## 14   0.6538    0.7692 BIOLOGY  0.34615  0.11538  0.3333       Q5
## 15   0.6923    0.8462 BIOLOGY  0.30769  0.15385  0.5000       Q6
## 16   0.6154    0.8462 BIOLOGY  0.38462  0.23077  0.6000       Q7
## 17   0.7949    0.6923  CODING  0.20513 -0.10256 -0.5000       Q8
## 18   0.7308    0.7308  CODING  0.26923  0.00000  0.0000       Q9
```

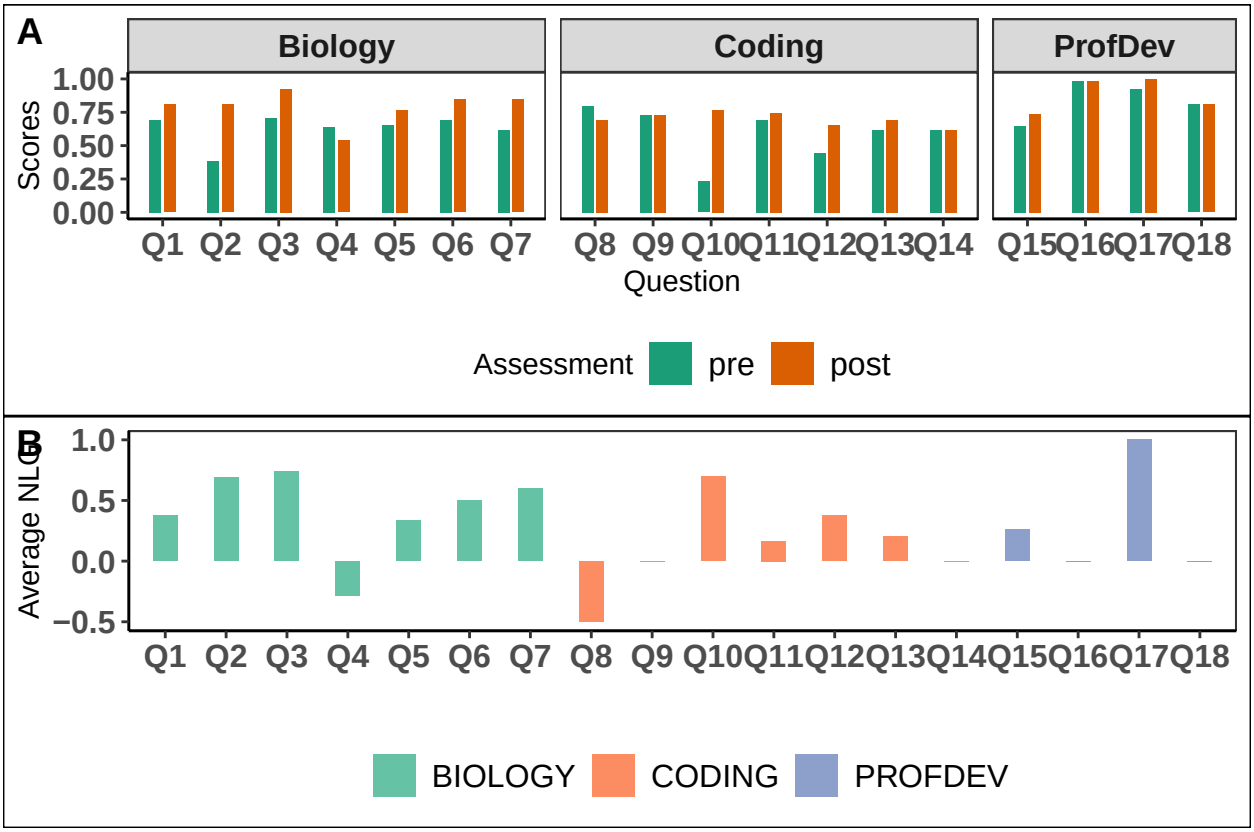
```
# title = 'Difference in average normalized learning gain
# (NLG) per question',

qmu_nlg_bar <- ggplot(data = qmu_stats, aes(x = question, y = nlg,
    fill = topic)) + geom_bar(width = 0.4, stat = "identity",
```

```
    position = position_dodge(0.5)) + scale_fill_brewer(palette = "Set2") +
    xlab("") + ylab("Average NLG") + labs(fill = "Assessment") +
    theme(legend.title = element_blank(), legend.position = "bottom",
        panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
        panel.background = element_blank(), axis.line = element_line(colour = "black")) +
    theme(legend.text = element_text(size = 12), legend.position = "bottom",
        axis.text = element_text(face = "bold", size = 12), axis.text.y.left = element_text(size = 12),
        plot.background = element_rect(color = "black"))
qmu_nlg_bar
```



Combine the plot with question scores and NLG.

```
# Use ggarrange to create a panel for both A. and B.
# library(ggpubr) #load in library for multi-panel figures
# put all three plots together into one multipanel plot
qmulti_plotq <- ggarrange(questions_bar_grid, qmu_nlg_bar, labels = c("A",
    "B"), ncol = 1, nrow = 2, widths = c(1, 1), common.legend = F,
    legend = "bottom") + theme(plot.background = element_rect(color = "black"))
# does the plot have a common legend add titles and labels
# to the multi-panel graph
qmulti_plotq <- annotate_figure(qmulti_plotq, top = text_grob("",
    color = "black", face = "bold", size = 11)) + scale_fill_hue(l = 40)
qmulti_plotq
```




```
ggsave(filename = "nlg.pdf", plot = qmulti_plotq, height = 5,
    width = 7)

# This plot works better stacked because the question
# numbers on the x-axis match up Side by side is not as
# legible
```

Investigating individual question responses Use the NLG to evaluate where there were increases, losses, and no changes in answers.

```
# Rearrange columns so questions and topics are first
nlg <- qmu_stats %>%
    relocate(question, .before = pre_mean) %>%
    relocate(topic, .after = question)
nlg
```

```
##    question   topic pre_mean post_mean from_max     diff     nlg
## 1        Q1 BIOLOGY   0.6923    0.8077  0.30769  0.11538  0.3750
## 2       Q10  CODING   0.2308    0.7692  0.76923  0.53846  0.7000
## 3       Q11  CODING   0.6923    0.7436  0.30769  0.05128  0.1667
## 4       Q12  CODING   0.4423    0.6538  0.55769  0.21154  0.3793
## 5       Q13  CODING   0.6154    0.6923  0.38462  0.07692  0.2000
## 6       Q14  CODING   0.6154    0.6154  0.38462  0.00000  0.0000
## 7       Q15 PROFDEV   0.6462    0.7385  0.35385  0.09231  0.2609
```

```
## 8       Q16 PROFDEV   0.9872    0.9872  0.01282  0.00000  0.0000
## 9       Q17 PROFDEV   0.9231    1.0000  0.07692  0.07692  1.0000
## 10      Q18 PROFDEV   0.8077    0.8077  0.19231  0.00000  0.0000
## 11       Q2 BIOLOGY   0.3846    0.8077  0.61538  0.42308  0.6875
## 12       Q3 BIOLOGY   0.7077    0.9231  0.29231  0.21538  0.7368
## 13       Q4 BIOLOGY   0.6410    0.5385  0.35897 -0.10256 -0.2857
## 14       Q5 BIOLOGY   0.6538    0.7692  0.34615  0.11538  0.3333
## 15       Q6 BIOLOGY   0.6923    0.8462  0.30769  0.15385  0.5000
## 16       Q7 BIOLOGY   0.6154    0.8462  0.38462  0.23077  0.6000
## 17       Q8  CODING   0.7949    0.6923  0.20513 -0.10256 -0.5000
## 18       Q9  CODING   0.7308    0.7308  0.26923  0.00000  0.0000
```

Significant gains in questions 2, 3, 10 (Q12 had a p-value of 0.053)

```
# Extract the question averages that showed positive
# normalized learning gain

pos_gains <- nlg %>%
    filter(nlg > "0.0")
pos_gains
```

```
##    question   topic pre_mean post_mean from_max    diff    nlg
## 1        Q1 BIOLOGY   0.6923    0.8077  0.30769 0.11538 0.3750
## 2       Q10  CODING   0.2308    0.7692  0.76923 0.53846 0.7000
## 3       Q11  CODING   0.6923    0.7436  0.30769 0.05128 0.1667
## 4       Q12  CODING   0.4423    0.6538  0.55769 0.21154 0.3793
## 5       Q13  CODING   0.6154    0.6923  0.38462 0.07692 0.2000
## 6       Q15 PROFDEV   0.6462    0.7385  0.35385 0.09231 0.2609
## 7       Q17 PROFDEV   0.9231    1.0000  0.07692 0.07692 1.0000
## 8        Q2 BIOLOGY   0.3846    0.8077  0.61538 0.42308 0.6875
## 9        Q3 BIOLOGY   0.7077    0.9231  0.29231 0.21538 0.7368
## 10       Q5 BIOLOGY   0.6538    0.7692  0.34615 0.11538 0.3333
## 11       Q6 BIOLOGY   0.6923    0.8462  0.30769 0.15385 0.5000
## 12       Q7 BIOLOGY   0.6154    0.8462  0.38462 0.23077 0.6000
```

```
# Extract the question averages that showed no normalized
# learning gain
no_gains <- nlg %>%
    filter(nlg == "0")
no_gains
```

```
##   question   topic pre_mean post_mean from_max diff nlg
## 1      Q14  CODING   0.6154    0.6154  0.38462    0   0
## 2      Q16 PROFDEV   0.9872    0.9872  0.01282    0   0
## 3      Q18 PROFDEV   0.8077    0.8077  0.19231    0   0
## 4       Q9  CODING   0.7308    0.7308  0.26923    0   0
```

```
# Extract the question averages that showed no normalized
# learning gain
neg_gains <- nlg %>%
```

```
    filter(nlg < "0")
neg_gains

# Investigate the answers and distractors of the negative
# gains to identify common misconceptions or gaps in
# knowledge There are two different formatting options for
# the check-all-that-apply format below

# ============================== Q4 analysis: Which are
# true about RNA and RNA sequencing experiments? (choose
# all true statements) ==============================

# Hardcode the question content
ans_post_per4_long <- data.frame(type = "post", alpha = c("A",
    "B", "C", "D", "E"), answer = c("RNA is more stable than DNA",
    "RNA is reverse transcribed into cDNA prior to sequencing",
    "In sequencing experiments the molecules (RNA or DNA) from the cell will be cut into shorter reads
    "The sequencing reads of a gene in an RNA-seq experiment represent a relative quantification of RNA
    "The sequence reads of a gene in a RNA-seq experiment are a measure of the total number of RNA reads
    percent = c("30.77", "84.62", "100.00", "69.23", "61.54"),
    q_type = c("Distractor", "Answer", "Answer", "Answer", "Distractor"))

ans_pre_per4_long <- data.frame(type = "pre", alpha = c("A",
    "B", "C", "D", "E"), answer = c("RNA is more stable than DNA",
    "RNA is reverse transcribed into cDNA prior to sequencing",
    "In sequencing experiments the molecules (RNA or DNA) from the cell will be cut into shorter reads
    "The sequencing reads of a gene in an RNA-seq experiment represent a relative quantification of RNA
    "The sequence reads of a gene in a RNA-seq experiment are a measure of the total number of RNA reads
    percent = c("0.00", "53.85", "100.00", "30.77", "61.54"),
    q_type = c("Distractor", "Answer", "Answer", "Answer", "Distractor"))

# combine the data frames vertically using rbind function
ans_per4_long <- ans_pre_per4_long %>%
    rbind(ans_post_per4_long)
view(ans_per4_long)

# Add the full answers with breaks '/n'
answer_labels4 <- c("RNA is more stable /nthan DNA", "*RNA is reverse transcribed /ninto cDNA prior to
    "*In sequencing experiments the /nmolecules (RNA or DNA) /nfrom the cell /nwill be cut into /nshorte
    "*The sequencing reads /nof a gene in an RNA-seq /nexperiment represent a /nrelative quantification
    "The sequence reads of /na gene in a RNA-seq /nexperiment are a /nmeasure of the total /nnumber of

# Use geom_tile to create the heatmap
hm4 <- ggplot(ans_per4_long, aes(answer, type, fill = percent)) +
    geom_tile(show.legend = FALSE) + scale_fill_brewer("RdYlGn") +
    geom_text(aes(label = paste0(percent, "%")), color = "black",
        fontface = "bold") + theme(plot.margin = margin(1, 1,
    1, 1, "cm")) + facet_grid(cols = vars(q_type), space = "free",
    scales = "free")

# Create the labels for the x-axis
hm4 <- hm4 + scale_x_discrete(labels = function(answer) str_wrap(answer,
    width = 20), position = "top")
```

```r
hm4 <- print(hm4 + labs(y = element_blank(), x = "Q4: Which are true about RNA and RNA sequencing experi

# ============================== Q8 analysis: Which are
# true about R? (choose all true statements)
# ==============================

# Hardcode the question content
ans_post_per8_long <- data.frame(type = "post", alpha = c("A",
    "B", "C", "D", "E", "F"), answer = c("There are a lot of published statistics and algorithms for bio
    "Code written in R is easy to read so you do not need to spend much time adding descriptive comments
    "Saving R scripts with the data you produced or analyzed allows you to easily reproduce, modify, and
    "R is a coding environment, but not a language", "R is a language, but not a coding environment",
    "R is a language and an environment for statistical computing and graphing"),
    percent = c("100.00", "38.46", "100.00", "0.00", "30.77",
        "76.92"), q_type = c("Answer", "Distractor", "Answer",
        "Distractor", "Distractor", "Answer"))

ans_pre_per8_long <- data.frame(type = "pre", alpha = c("A",
    "B", "C", "D", "E", "F"), answer = c("There are a lot of published statistics and algorithms for bio
    "Code written in R is easy to read so you do not need to spend much time adding descriptive comments
    "Saving R scripts with the data you produced or analyzed allows you to easily reproduce, modify, and
    "R is a coding environment, but not a language", "R is a language, but not a coding environment",
    "R is a language and an environment for statistical computing and graphing"),
    percent = c("100.00", "15.38", "84.62", "0.00", "15.38",
        "84.62"), q_type = c("Answer", "Distractor", "Answer",
        "Distractor", "Distractor", "Answer"))

# combine the data frames vertically using rbind function
ans_per8_long <- ans_pre_per8_long %>%
    rbind(ans_post_per8_long)
view(ans_per4_long)

hm8 <- ggplot(ans_per8_long, aes(answer, type, fill = percent)) +
    geom_tile(show.legend = FALSE) + scale_fill_brewer("Blues") +
    geom_text(aes(label = paste0(percent, "%")), color = "black",
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + fontface
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + =
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + "bold")
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + +
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + #
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + theme(plot.margin
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + =
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + margin(1,1,1,1,
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + 'cm'))
        fontface = "bold") + # theme(plot.margin = margin(1,1,1,1, 'cm')) + +
facet_grid(cols = vars(q_type), space = "free", scales = "free") +
    theme(strip.text.x = element_text(size = 12), legend.title = element_blank(),
        legend.text = element_text(size = 12), legend.position = "none",
        axis.text = element_text(face = "bold", size = 9), axis.text.y.left = element_text(size = 12))

hm8 <- hm8 + scale_x_discrete(labels = function(answer) str_wrap(answer,
    width = 20))
```

```
hm8 <- print(hm8 + labs(y = element_blank(), x = element_blank(),
    title = "Q8: Which are true about R? Choose all true statements"))
```

Investigate responses for negative NLG questions using heatmaps

Section 2: How does a remote CURE affect student comfort levels in computational research?

Likert analysis

- R programming
- Command line
- Self-reported skill level
- Expertise levels in computational research

19. How would you describe your comfort level with using a command line interface to interact with a Linux/Unix command-line style environment?

20. How would you describe your comfort level with programming in R?

22. How comfortable are you asking your peers coding questions in an open class forum?

23. How comfortable are you reading and interpreting a scientific paper?

24. How comfortable are you writing a scientific paper?

Scale for questions Q19, Q20, Q22, Q23, Q24 - Very uncomfortable | 1 - Uncomfortable | 2 - neutral | 3 - comfortable | 4 - Very comfortable | 5

- *If multiple were indicated by the student, the lowest level was selected.*

21. How would you describe your level of coding expertise using any programming language?

Scale for question Q21 - Novice | 1 - Advanced beginner | 2 - Competent | 3 - Proficient | 4 - Expert | 5

- *If multiple were indicated by the student, the lowest level was selected.*

25. What is your experience level doing computational research up until this point?

Scale for question Q25 - I've had little to no research experience | 1 - I have completed a course-based research experience (CURE) | 2 - I currently do computational research | 3 - I have done non-computational research | 4 - I have co-authored published research | 5 - I don't want to do research | 0

- *If multiple were indicated by the student, the lowest level was selected.*

```r
# Upload likert datasets on personal feelings

pf <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_anon_datas
View(pf)

pf_pre <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_anon_da
View(pf_pre)

pf_post <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_anon_
View(pf_post)

# Create a summary of pre and post personal feeling scores
sum_pf_pre <- summary(pf_pre)
sum_pf_post <- summary(pf_post)

# Separate the pre and post scores
pf_pre_topic <- pf %>%
    filter(pf$type == "pre")
pf_pre_topic
```

```
##    student question             topic type score
## 1       S1      Q19             linux  pre     3
## 2       S1      Q20      Rprogramming  pre     1
## 3       S1      Q21         expertise  pre     1
## 4       S1      Q22     collaborating  pre     3
## 5       S1      Q23 writing_sci_paper  pre     4
## 6       S1      Q24 reading_sci_paper  pre     4
## 7       S2      Q19             linux  pre     4
## 8       S2      Q20      Rprogramming  pre     2
## 9       S2      Q21         expertise  pre     2
## 10      S2      Q22     collaborating  pre     4
## 11      S2      Q23 writing_sci_paper  pre     5
## 12      S2      Q24 reading_sci_paper  pre     4
## 13      S3      Q19             linux  pre     5
## 14      S3      Q20      Rprogramming  pre     3
## 15      S3      Q21         expertise  pre     4
## 16      S3      Q22     collaborating  pre     5
## 17      S3      Q23 writing_sci_paper  pre     5
## 18      S3      Q24 reading_sci_paper  pre     5
## 19      S4      Q19             linux  pre     3
## 20      S4      Q20      Rprogramming  pre     3
## 21      S4      Q21         expertise  pre     2
## 22      S4      Q22     collaborating  pre     4
## 23      S4      Q23 writing_sci_paper  pre     3
## 24      S4      Q24 reading_sci_paper  pre     2
## 25      S5      Q19             linux  pre     4
## 26      S5      Q20      Rprogramming  pre     1
## 27      S5      Q21         expertise  pre     1
## 28      S5      Q22     collaborating  pre     3
## 29      S5      Q23 writing_sci_paper  pre     5
## 30      S5      Q24 reading_sci_paper  pre     4
## 31      S6      Q19             linux  pre     3
## 32      S6      Q20      Rprogramming  pre     3
```

```
## 33      S6      Q21         expertise  pre     2
## 34      S6      Q22     collaborating  pre     2
## 35      S6      Q23 writing_sci_paper  pre     4
## 36      S6      Q24 reading_sci_paper  pre     4
## 37      S7      Q19             linux  pre     5
## 38      S7      Q20      Rprogramming  pre     5
## 39      S7      Q21         expertise  pre     4
## 40      S7      Q22     collaborating  pre     4
## 41      S7      Q23 writing_sci_paper  pre     5
## 42      S7      Q24 reading_sci_paper  pre     3
## 43      S8      Q19             linux  pre     3
## 44      S8      Q20      Rprogramming  pre     2
## 45      S8      Q21         expertise  pre     2
## 46      S8      Q22     collaborating  pre     4
## 47      S8      Q23 writing_sci_paper  pre     4
## 48      S8      Q24 reading_sci_paper  pre     3
## 49      S9      Q19             linux  pre     4
## 50      S9      Q20      Rprogramming  pre     2
## 51      S9      Q21         expertise  pre     2
## 52      S9      Q22     collaborating  pre     5
## 53      S9      Q23 writing_sci_paper  pre     5
## 54      S9      Q24 reading_sci_paper  pre     3
## 55     S10      Q19             linux  pre     4
## 56     S10      Q20      Rprogramming  pre     3
## 57     S10      Q21         expertise  pre     2
## 58     S10      Q22     collaborating  pre     4
## 59     S10      Q23 writing_sci_paper  pre     4
## 60     S10      Q24 reading_sci_paper  pre     3
## 61     S11      Q19             linux  pre     3
## 62     S11      Q20      Rprogramming  pre     3
## 63     S11      Q21         expertise  pre     2
## 64     S11      Q22     collaborating  pre     4
## 65     S11      Q23 writing_sci_paper  pre     4
## 66     S11      Q24 reading_sci_paper  pre     3
## 67     S12      Q19             linux  pre     3
## 68     S12      Q20      Rprogramming  pre     1
## 69     S12      Q21         expertise  pre     1
## 70     S12      Q22     collaborating  pre     4
## 71     S12      Q23 writing_sci_paper  pre     4
## 72     S12      Q24 reading_sci_paper  pre     1
## 73     S13      Q19             linux  pre     4
## 74     S13      Q20      Rprogramming  pre     3
## 75     S13      Q21         expertise  pre     3
## 76     S13      Q22     collaborating  pre     5
## 77     S13      Q23 writing_sci_paper  pre     5
## 78     S13      Q24 reading_sci_paper  pre     4
```

```
pf_post_topic <- pf %>%
    filter(pf$type == "post")
pf_pre_topic
```

```
##    student question             topic type score
## 1       S1      Q19             linux  pre     3
## 2       S1      Q20      Rprogramming  pre     1
```

```
## 3       S1      Q21         expertise  pre     1
## 4       S1      Q22     collaborating  pre     3
## 5       S1      Q23 writing_sci_paper  pre     4
## 6       S1      Q24 reading_sci_paper  pre     4
## 7       S2      Q19             linux  pre     4
## 8       S2      Q20      Rprogramming  pre     2
## 9       S2      Q21         expertise  pre     2
## 10      S2      Q22     collaborating  pre     4
## 11      S2      Q23 writing_sci_paper  pre     5
## 12      S2      Q24 reading_sci_paper  pre     4
## 13      S3      Q19             linux  pre     5
## 14      S3      Q20      Rprogramming  pre     3
## 15      S3      Q21         expertise  pre     4
## 16      S3      Q22     collaborating  pre     5
## 17      S3      Q23 writing_sci_paper  pre     5
## 18      S3      Q24 reading_sci_paper  pre     5
## 19      S4      Q19             linux  pre     3
## 20      S4      Q20      Rprogramming  pre     3
## 21      S4      Q21         expertise  pre     2
## 22      S4      Q22     collaborating  pre     4
## 23      S4      Q23 writing_sci_paper  pre     3
## 24      S4      Q24 reading_sci_paper  pre     2
## 25      S5      Q19             linux  pre     4
## 26      S5      Q20      Rprogramming  pre     1
## 27      S5      Q21         expertise  pre     1
## 28      S5      Q22     collaborating  pre     3
## 29      S5      Q23 writing_sci_paper  pre     5
## 30      S5      Q24 reading_sci_paper  pre     4
## 31      S6      Q19             linux  pre     3
## 32      S6      Q20      Rprogramming  pre     3
## 33      S6      Q21         expertise  pre     2
## 34      S6      Q22     collaborating  pre     2
## 35      S6      Q23 writing_sci_paper  pre     4
## 36      S6      Q24 reading_sci_paper  pre     4
## 37      S7      Q19             linux  pre     5
## 38      S7      Q20      Rprogramming  pre     5
## 39      S7      Q21         expertise  pre     4
## 40      S7      Q22     collaborating  pre     4
## 41      S7      Q23 writing_sci_paper  pre     5
## 42      S7      Q24 reading_sci_paper  pre     3
## 43      S8      Q19             linux  pre     3
## 44      S8      Q20      Rprogramming  pre     2
## 45      S8      Q21         expertise  pre     2
## 46      S8      Q22     collaborating  pre     4
## 47      S8      Q23 writing_sci_paper  pre     4
## 48      S8      Q24 reading_sci_paper  pre     3
## 49      S9      Q19             linux  pre     4
## 50      S9      Q20      Rprogramming  pre     2
## 51      S9      Q21         expertise  pre     2
## 52      S9      Q22     collaborating  pre     5
## 53      S9      Q23 writing_sci_paper  pre     5
## 54      S9      Q24 reading_sci_paper  pre     3
## 55     S10      Q19             linux  pre     4
## 56     S10      Q20      Rprogramming  pre     3
```

```
## 57     S10      Q21         expertise  pre     2
## 58     S10      Q22     collaborating  pre     4
## 59     S10      Q23 writing_sci_paper  pre     4
## 60     S10      Q24 reading_sci_paper  pre     3
## 61     S11      Q19             linux  pre     3
## 62     S11      Q20      Rprogramming  pre     3
## 63     S11      Q21         expertise  pre     2
## 64     S11      Q22     collaborating  pre     4
## 65     S11      Q23 writing_sci_paper  pre     4
## 66     S11      Q24 reading_sci_paper  pre     3
## 67     S12      Q19             linux  pre     3
## 68     S12      Q20      Rprogramming  pre     1
## 69     S12      Q21         expertise  pre     1
## 70     S12      Q22     collaborating  pre     4
## 71     S12      Q23 writing_sci_paper  pre     4
## 72     S12      Q24 reading_sci_paper  pre     1
## 73     S13      Q19             linux  pre     4
## 74     S13      Q20      Rprogramming  pre     3
## 75     S13      Q21         expertise  pre     3
## 76     S13      Q22     collaborating  pre     5
## 77     S13      Q23 writing_sci_paper  pre     5
## 78     S13      Q24 reading_sci_paper  pre     4
```

```
# Summarize the mean and the standard deviation of pre and
# post scores
summary_pf_pre <- group_by(pf_pre_topic, question) %>%
    dplyr::summarize(count = n(), mean = mean(score, na.rm = TRUE),
        sd = sd(score, na.rm = TRUE))
write.csv(summary_pf_pre, file = "q_sum_pre.csv", row.names = FALSE)


summary_pf_post <- group_by(pf_post_topic, question) %>%
    dplyr::summarize(count = n(), mean = mean(score, na.rm = TRUE),
        sd = sd(score, na.rm = TRUE))
summary_pf_post
```

```
## # A tibble: 6 x 4
##   question count  mean    sd
##   <chr>    <int> <dbl> <dbl>
## 1 Q19         13  3.69 0.855
## 2 Q20         13  3.15 0.899
## 3 Q21         13  2.54 1.20
## 4 Q22         13  3.85 0.899
## 5 Q23         13  3.92 0.954
## 6 Q24         13  3.15 0.987
```

```
# Create density plots to see a brief summary of the Likert
# scores Set up the data for the pretest
pf_pre$Q19 = factor(pf_pre$Q19, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_pre$Q20 = factor(pf_pre$Q20, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)
```

```
pf_pre$Q22 = factor(pf_pre$Q22, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_pre$Q23 = factor(pf_pre$Q23, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_pre$Q24 = factor(pf_pre$Q24, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

# Set up the data for the post-test
pf_post$Q19 = factor(pf_post$Q19, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_post$Q20 = factor(pf_post$Q20, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_post$Q22 = factor(pf_post$Q22, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_post$Q23 = factor(pf_post$Q23, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

pf_post$Q24 = factor(pf_post$Q24, levels = c("1", "2", "3", "4",
    "5"), ordered = TRUE)

# Remove the columns with non-Likert data
drop <- c("student", "Q21")
pf_pre_density <- pf_pre[, !(names(pf_pre) %in% drop)]
pf_post_density <- pf_post[, !(names(pf_post) %in% drop)]

# Rename columns to question descriptions
setnames(pf_pre_density, old = c("Q19", "Q20", "Q22", "Q23",
    "Q24"), new = c("Linux", "R Programming", "Online collaboration",
    "Reading papers", "Writing papers"))
pf_pre_density
```

```
##    Linux R Programming Online collaboration Reading papers Writing papers
## 1      3             1                     3              4              4
## 2      4             2                     4              5              4
## 3      5             3                     5              5              5
## 4      3             3                     4              3              2
## 5      4             1                     3              5              4
## 6      3             3                     2              4              4
## 7      5             5                     4              5              3
## 8      3             2                     4              4              3
## 9      4             2                     5              5              3
## 10     4             3                     4              4              3
## 11     3             3                     4              4              3
## 12     3             1                     4              4              1
## 13     4             3                     5              5              4
```

```
setnames(pf_post_density, old = c("Q19", "Q20", "Q22", "Q23",
    "Q24"), new = c("Linux", "R Programming", "Online collaboration",
    "Reading papers", "Writing papers"))
pf_post_density
```

```
##    Linux R Programming Online collaboration Reading papers Writing papers
## 1      4             3                    3              4              4
## 2      3             4                    5              5              5
## 3      5             4                    5              5              5
## 4      3             3                    4              3              3
## 5      4             3                    3              4              3
## 6      3             3                    3              3              3
## 7      5             5                    5              5              3
## 8      3             2                    3              3              2
## 9      3             2                    4              4              3
## 10     4             3                    3              2              2
## 11     3             3                    3              4              3
## 12     3             2                    4              4              2
## 13     5             4                    5              5              3
```

```
# psych library to use head/tails function to view data
headTail(pf_pre_density)
```

```
##     Linux R.Programming Online.collaboration Reading.papers Writing.papers
## 1       3             1                    3              4              4
## 2       4             2                    4              5              4
## 3       5             3                    5              5              5
## 4       3             3                    4              3              2
## ...  <NA>          <NA>                 <NA>           <NA>           <NA>
## 10      4             3                    4              4              3
## 11      3             3                    4              4              3
## 12      3             1                    4              4              1
## 13      4             3                    5              5              4
```

```
str(pf_pre_density)
```

```
## 'data.frame':    13 obs. of  5 variables:
##  $ Linux               : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 3 4 5 3 4 3 5 3 4 4 ...
##  $ R Programming       : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 1 2 3 3 1 3 5 2 2 3 ...
##  $ Online collaboration: Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 3 4 5 4 3 2 4 4 5 4 ...
##  $ Reading papers      : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 4 5 5 3 5 4 5 4 5 4 ...
##  $ Writing papers      : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 4 4 5 2 4 4 3 3 3 3 ...
```

```
summary(pf_pre_density)
```

```
##  Linux R Programming Online collaboration Reading papers Writing papers
##  1:0   1:3           1:0                  1:0            1:1
##  2:0   2:3           2:1                  2:0            2:1
##  3:6   3:6           3:2                  3:1            3:5
##  4:5   4:0           4:7                  4:6            4:5
##  5:2   5:1           5:3                  5:6            5:1
```

```
headTail(pf_post_density)
```

```
##     Linux R.Programming Online.collaboration Reading.papers Writing.papers
## 1       4             3                    3              4              4
## 2       3             4                    5              5              5
## 3       5             4                    5              5              5
## 4       3             3                    4              3              3
## ...  <NA>          <NA>                 <NA>           <NA>           <NA>
## 10      4             3                    3              2              2
## 11      3             3                    3              4              3
## 12      3             2                    4              4              2
## 13      5             4                    5              5              3
```

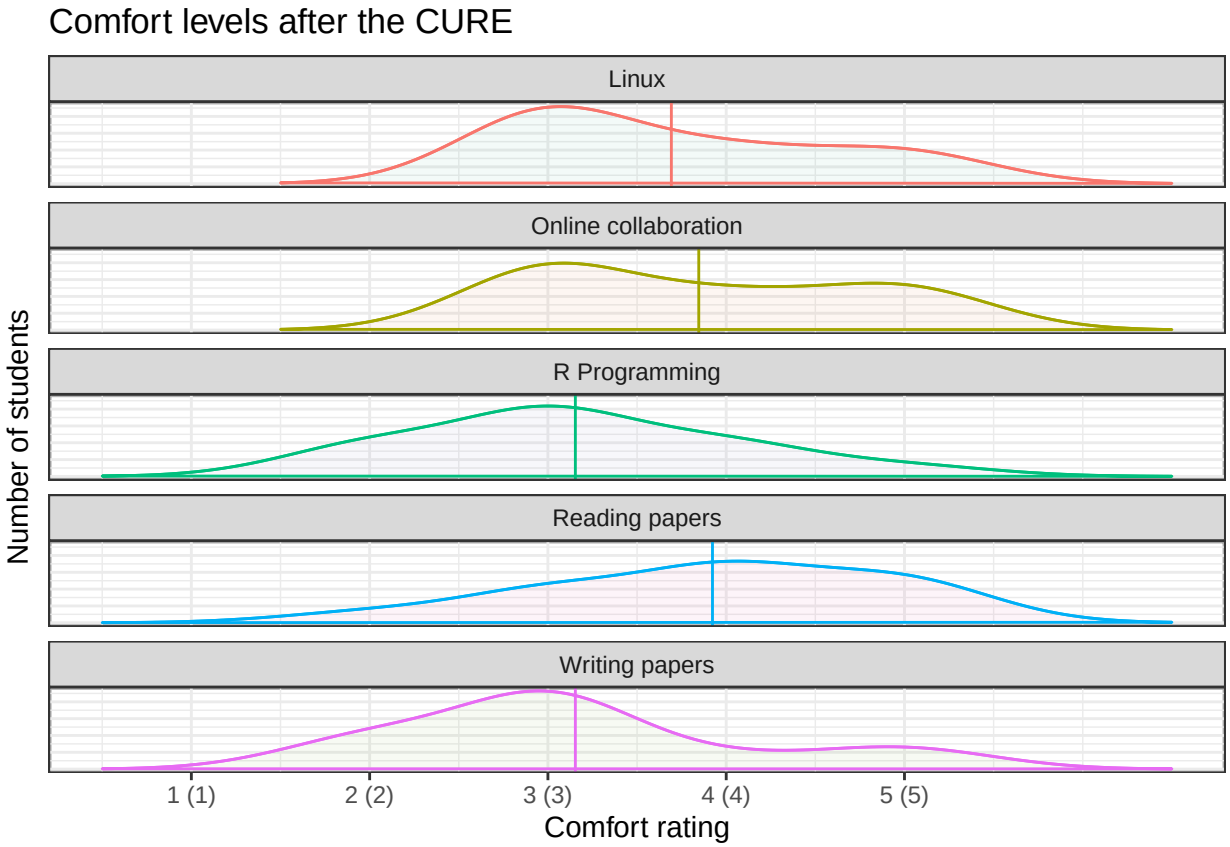
```
str(pf_post_density)
```

```
## 'data.frame':    13 obs. of  5 variables:
##  $ Linux               : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 4 3 5 3 4 3 5 3 3 4 ...
##  $ R Programming       : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 3 4 4 3 3 3 5 2 2 3 ...
##  $ Online collaboration: Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 3 5 5 4 3 3 5 3 4 3 ...
##  $ Reading papers      : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 4 5 5 3 4 3 5 3 4 2 ...
##  $ Writing papers      : Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 4 5 5 3 3 3 3 2 3 2 ...
```

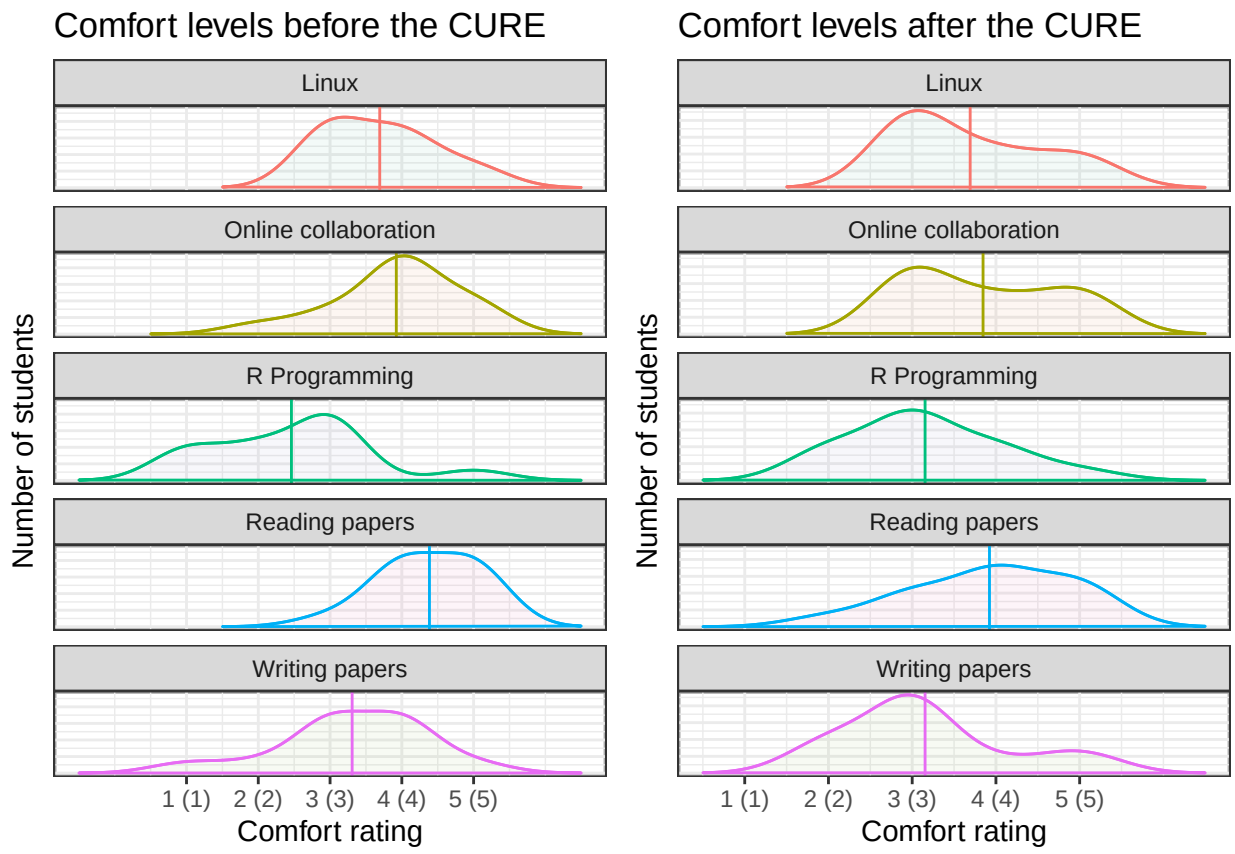
```
summary(pf_post_density)
```

```
##  Linux R Programming Online collaboration Reading papers Writing papers
##  1:0   1:0           1:0                  1:0            1:0
##  2:0   2:3           2:0                  2:1            2:3
##  3:7   3:6           3:6                  3:3            3:7
##  4:3   4:3           4:3                  4:5            4:1
##  5:3   5:1           5:4                  5:4            5:2
```

```
# Using the likert package Create the pre likert density
# plot
Result_pre = likert(pf_pre_density)

pf_plot_pre <- plot(Result_pre, type = "density", facet = TRUE,
    bw = 0.5) + labs(title = "Comfort levels before the CURE",
    y = "Number of students", x = "Comfort rating") + scale_fill_brewer(palette = "Dark2")


# Create the post likert density plot
Result_post = likert(pf_post_density)

pf_plot_post <- plot(Result_post, type = "density", facet = TRUE,
    bw = 0.5) + labs(title = "Comfort levels after the CURE",
    y = "Number of students", x = "Comfort rating") + scale_fill_brewer(palette = "Dark2")
pf_plot_post
```




```
# Use gridExtra to put pre post side by side
grid.arrange(pf_plot_pre, pf_plot_post, ncol = 2)
```




```
mylevels <- c("Very uncomfortable", "Uncomfortable", "Neutral",
    "Comfortable", "Very comfortable")


# ============================================================
# # Q21: Self-rated skill level in coding expertise
# ============================================================
# # Filter for Q21: Coding expertise
pf21 <- pf %>%
    filter(pf$question == "Q21")

pf_new <- pf
pf_new$type <- factor(pf_new$type, c("pre", "post"))
pf_new <- pf_new %>%
    filter(pf_new$question != "Q21")
pf_new
```

```
##     student question             topic type score
## 1        S1      Q19             linux  pre     3
## 2        S1      Q20      Rprogramming  pre     1
## 3        S1      Q22     collaborating  pre     3
## 4        S1      Q23 writing_sci_paper  pre     4
## 5        S1      Q24 reading_sci_paper  pre     4
## 6        S2      Q19             linux  pre     4
## 7        S2      Q20      Rprogramming  pre     2
```

```
## 8        S2      Q22     collaborating  pre     4
## 9        S2      Q23 writing_sci_paper  pre     5
## 10       S2      Q24 reading_sci_paper  pre     4
## 11       S3      Q19             linux  pre     5
## 12       S3      Q20      Rprogramming  pre     3
## 13       S3      Q22     collaborating  pre     5
## 14       S3      Q23 writing_sci_paper  pre     5
## 15       S3      Q24 reading_sci_paper  pre     5
## 16       S4      Q19             linux  pre     3
## 17       S4      Q20      Rprogramming  pre     3
## 18       S4      Q22     collaborating  pre     4
## 19       S4      Q23 writing_sci_paper  pre     3
## 20       S4      Q24 reading_sci_paper  pre     2
## 21       S5      Q19             linux  pre     4
## 22       S5      Q20      Rprogramming  pre     1
## 23       S5      Q22     collaborating  pre     3
## 24       S5      Q23 writing_sci_paper  pre     5
## 25       S5      Q24 reading_sci_paper  pre     4
## 26       S6      Q19             linux  pre     3
## 27       S6      Q20      Rprogramming  pre     3
## 28       S6      Q22     collaborating  pre     2
## 29       S6      Q23 writing_sci_paper  pre     4
## 30       S6      Q24 reading_sci_paper  pre     4
## 31       S7      Q19             linux  pre     5
## 32       S7      Q20      Rprogramming  pre     5
## 33       S7      Q22     collaborating  pre     4
## 34       S7      Q23 writing_sci_paper  pre     5
## 35       S7      Q24 reading_sci_paper  pre     3
## 36       S8      Q19             linux  pre     3
## 37       S8      Q20      Rprogramming  pre     2
## 38       S8      Q22     collaborating  pre     4
## 39       S8      Q23 writing_sci_paper  pre     4
## 40       S8      Q24 reading_sci_paper  pre     3
## 41       S9      Q19             linux  pre     4
## 42       S9      Q20      Rprogramming  pre     2
## 43       S9      Q22     collaborating  pre     5
## 44       S9      Q23 writing_sci_paper  pre     5
## 45       S9      Q24 reading_sci_paper  pre     3
## 46      S10      Q19             linux  pre     4
## 47      S10      Q20      Rprogramming  pre     3
## 48      S10      Q22     collaborating  pre     4
## 49      S10      Q23 writing_sci_paper  pre     4
## 50      S10      Q24 reading_sci_paper  pre     3
## 51      S11      Q19             linux  pre     3
## 52      S11      Q20      Rprogramming  pre     3
## 53      S11      Q22     collaborating  pre     4
## 54      S11      Q23 writing_sci_paper  pre     4
## 55      S11      Q24 reading_sci_paper  pre     3
## 56      S12      Q19             linux  pre     3
## 57      S12      Q20      Rprogramming  pre     1
## 58      S12      Q22     collaborating  pre     4
## 59      S12      Q23 writing_sci_paper  pre     4
## 60      S12      Q24 reading_sci_paper  pre     1
## 61      S13      Q19             linux  pre     4
```

```
## 62      S13      Q20      Rprogramming  pre     3
## 63      S13      Q22     collaborating  pre     5
## 64      S13      Q23 writing_sci_paper  pre     5
## 65      S13      Q24 reading_sci_paper  pre     4
## 66       S1      Q19             linux post     4
## 67       S1      Q20      Rprogramming post     3
## 68       S1      Q22     collaborating post     3
## 69       S1      Q23 writing_sci_paper post     4
## 70       S1      Q24 reading_sci_paper post     4
## 71       S2      Q19             linux post     3
## 72       S2      Q20      Rprogramming post     4
## 73       S2      Q22     collaborating post     5
## 74       S2      Q23 writing_sci_paper post     5
## 75       S2      Q24 reading_sci_paper post     5
## 76       S3      Q19             linux post     5
## 77       S3      Q20      Rprogramming post     4
## 78       S3      Q22     collaborating post     5
## 79       S3      Q23 writing_sci_paper post     5
## 80       S3      Q24 reading_sci_paper post     5
## 81       S4      Q19             linux post     3
## 82       S4      Q20      Rprogramming post     3
## 83       S4      Q22     collaborating post     4
## 84       S4      Q23 writing_sci_paper post     3
## 85       S4      Q24 reading_sci_paper post     3
## 86       S5      Q19             linux post     4
## 87       S5      Q20      Rprogramming post     3
## 88       S5      Q22     collaborating post     3
## 89       S5      Q23 writing_sci_paper post     4
## 90       S5      Q24 reading_sci_paper post     3
## 91       S6      Q19             linux post     3
## 92       S6      Q20      Rprogramming post     3
## 93       S6      Q22     collaborating post     3
## 94       S6      Q23 writing_sci_paper post     3
## 95       S6      Q24 reading_sci_paper post     3
## 96       S7      Q19             linux post     5
## 97       S7      Q20      Rprogramming post     5
## 98       S7      Q22     collaborating post     5
## 99       S7      Q23 writing_sci_paper post     5
## 100      S7      Q24 reading_sci_paper post     3
## 101      S8      Q19             linux post     3
## 102      S8      Q20      Rprogramming post     2
## 103      S8      Q22     collaborating post     3
## 104      S8      Q23 writing_sci_paper post     3
## 105      S8      Q24 reading_sci_paper post     2
## 106      S9      Q19             linux post     3
## 107      S9      Q20      Rprogramming post     2
## 108      S9      Q22     collaborating post     4
## 109      S9      Q23 writing_sci_paper post     4
## 110      S9      Q24 reading_sci_paper post     3
## 111     S10      Q19             linux post     4
## 112     S10      Q20      Rprogramming post     3
## 113     S10      Q22     collaborating post     3
## 114     S10      Q23 writing_sci_paper post     2
## 115     S10      Q24 reading_sci_paper post     2
```

```
## 116     S11      Q19             linux post     3
## 117     S11      Q20      Rprogramming post     3
## 118     S11      Q22     collaborating post     3
## 119     S11      Q23 writing_sci_paper post     4
## 120     S11      Q24 reading_sci_paper post     3
## 121     S12      Q19             linux post     3
## 122     S12      Q20      Rprogramming post     2
## 123     S12      Q22     collaborating post     4
## 124     S12      Q23 writing_sci_paper post     4
## 125     S12      Q24 reading_sci_paper post     2
## 126     S13      Q19             linux post     5
## 127     S13      Q20      Rprogramming post     4
## 128     S13      Q22     collaborating post     5
## 129     S13      Q23 writing_sci_paper post     5
## 130     S13      Q24 reading_sci_paper post     3
```

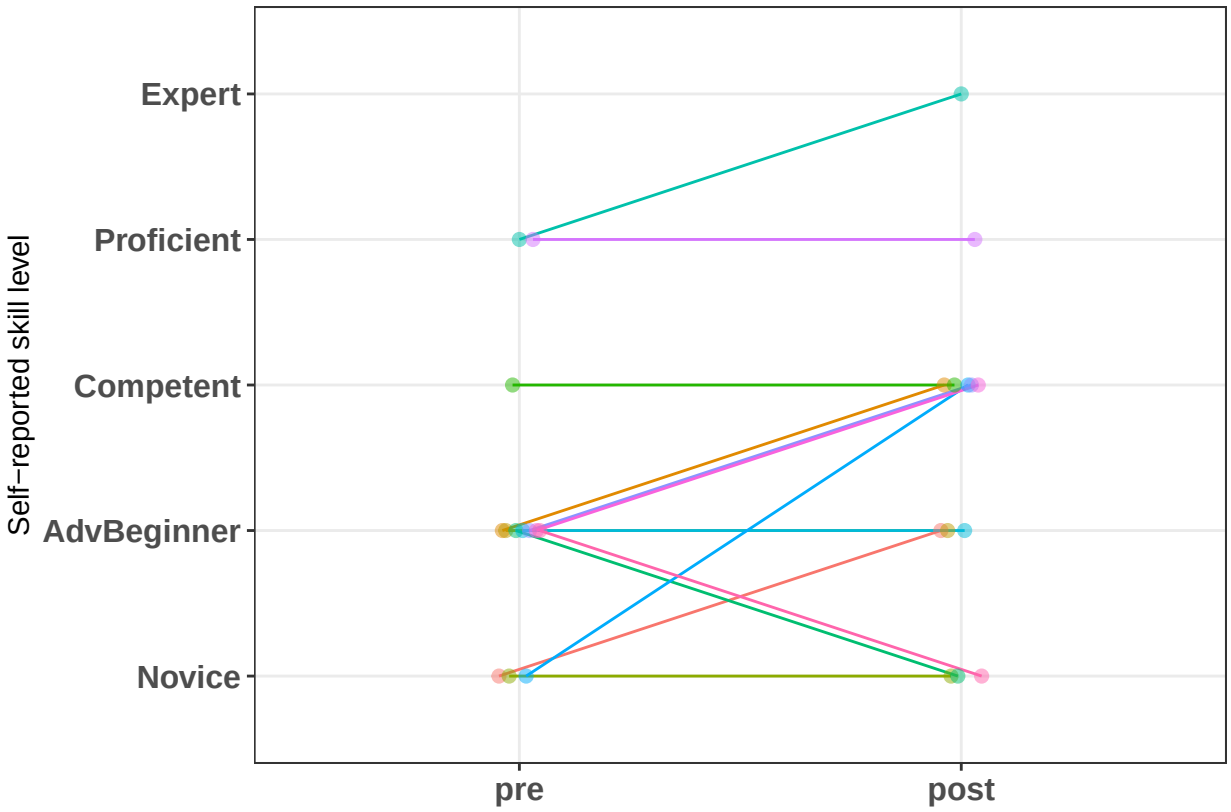
```
# Optional: Linear modeling of SRSL scores my_mod <-
# lm(score ~ type, pf) summary(my_mod) plot(my_mod) my_mod2
# <- lm(score ~ type + topic, pf) summary(my_mod2)
# plot(my_mod)

pf_21 <- pf %>%
    filter(pf$question == "Q21")
pf_21 <- data.frame(pf_21, expertise = pf_21$score)
pf_21
```

```
##    student question     topic type score expertise
## 1       S1      Q21 expertise  pre     1         1
## 2       S2      Q21 expertise  pre     2         2
## 3       S3      Q21 expertise  pre     4         4
## 4       S4      Q21 expertise  pre     2         2
## 5       S5      Q21 expertise  pre     1         1
## 6       S6      Q21 expertise  pre     2         2
## 7       S7      Q21 expertise  pre     4         4
## 8       S8      Q21 expertise  pre     2         2
## 9       S9      Q21 expertise  pre     2         2
## 10     S10      Q21 expertise  pre     2         2
## 11     S11      Q21 expertise  pre     2         2
## 12     S12      Q21 expertise  pre     1         1
## 13     S13      Q21 expertise  pre     3         3
## 14      S1      Q21 expertise post     2         2
## 15      S2      Q21 expertise post     1         1
## 16      S3      Q21 expertise post     5         5
## 17      S4      Q21 expertise post     2         2
## 18      S5      Q21 expertise post     3         3
## 19      S6      Q21 expertise post     3         3
## 20      S7      Q21 expertise post     4         4
## 21      S8      Q21 expertise post     3         3
## 22      S9      Q21 expertise post     1         1
## 23     S10      Q21 expertise post     3         3
## 24     S11      Q21 expertise post     2         2
## 25     S12      Q21 expertise post     1         1
## 26     S13      Q21 expertise post     3         3
```

```
# Replace numeric under Expertise col to the full string of
# the skill level
pf_21$expertise[pf_21$expertise == "1"] <- "Novice"
pf_21$expertise[pf_21$expertise == "2"] <- "Advanced Beginner"
pf_21$expertise[pf_21$expertise == "3"] <- "Competent"
pf_21$expertise[pf_21$expertise == "4"] <- "Proficient"
pf_21$expertise[pf_21$expertise == "5"] <- "Expert"
pf_21
```

```
##    student question     topic type score         expertise
## 1       S1      Q21 expertise  pre     1            Novice
## 2       S2      Q21 expertise  pre     2 Advanced Beginner
## 3       S3      Q21 expertise  pre     4        Proficient
## 4       S4      Q21 expertise  pre     2 Advanced Beginner
## 5       S5      Q21 expertise  pre     1            Novice
## 6       S6      Q21 expertise  pre     2 Advanced Beginner
## 7       S7      Q21 expertise  pre     4        Proficient
## 8       S8      Q21 expertise  pre     2 Advanced Beginner
## 9       S9      Q21 expertise  pre     2 Advanced Beginner
## 10     S10      Q21 expertise  pre     2 Advanced Beginner
## 11     S11      Q21 expertise  pre     2 Advanced Beginner
## 12     S12      Q21 expertise  pre     1            Novice
## 13     S13      Q21 expertise  pre     3         Competent
## 14      S1      Q21 expertise post     2 Advanced Beginner
## 15      S2      Q21 expertise post     1            Novice
## 16      S3      Q21 expertise post     5            Expert
## 17      S4      Q21 expertise post     2 Advanced Beginner
## 18      S5      Q21 expertise post     3         Competent
## 19      S6      Q21 expertise post     3         Competent
## 20      S7      Q21 expertise post     4        Proficient
## 21      S8      Q21 expertise post     3         Competent
## 22      S9      Q21 expertise post     1            Novice
## 23     S10      Q21 expertise post     3         Competent
## 24     S11      Q21 expertise post     2 Advanced Beginner
## 25     S12      Q21 expertise post     1            Novice
## 26     S13      Q21 expertise post     3         Competent
```

```
pf_21_sorted <- pf_21 %>%
    arrange(student, expertise)

posdod <- position_dodge(0.1)

srsl <- ggplot(pf_21_sorted, aes(x = factor(type, level = c("pre",
    "post")), y = factor(score), col = student, group = student)) +
    geom_line(show.legend = F, position = posdod, size = 0.5) +
    geom_point(data = pf_21_sorted, size = 2, position = posdod,
        alpha = 0.5) + ylab("Self-reported skill level") + xlab("") +
    theme(strip.text.x = element_text(size = 12), legend.position = "none",
        axis.text = element_text(face = "bold", size = 12), axis.text.y.left = element_text(size = 12))

srsl + scale_y_discrete(breaks = c("1", "2", "3", "4", "5"),
    labels = c("Novice", "AdvBeginner", "Competent", "Proficient",
        "Expert"))
```




```
pf_21_pre <- pf_21 %>%
    filter(pf_21$type == "pre")
pf_21_pre
```

```
##    student question     topic type score         expertise
## 1       S1      Q21 expertise  pre     1             Novice
## 2       S2      Q21 expertise  pre     2 Advanced Beginner
## 3       S3      Q21 expertise  pre     4        Proficient
## 4       S4      Q21 expertise  pre     2 Advanced Beginner
## 5       S5      Q21 expertise  pre     1             Novice
## 6       S6      Q21 expertise  pre     2 Advanced Beginner
## 7       S7      Q21 expertise  pre     4        Proficient
## 8       S8      Q21 expertise  pre     2 Advanced Beginner
## 9       S9      Q21 expertise  pre     2 Advanced Beginner
## 10     S10      Q21 expertise  pre     2 Advanced Beginner
## 11     S11      Q21 expertise  pre     2 Advanced Beginner
## 12     S12      Q21 expertise  pre     1             Novice
## 13     S13      Q21 expertise  pre     3         Competent
```

```
pf_21_post <- pf_21 %>%
    filter(pf_21$type == "post")
pf_21_post
```

```
##    student question     topic type score         expertise
```

```
## 1       S1      Q21 expertise post     2 Advanced Beginner
## 2       S2      Q21 expertise post     1            Novice
## 3       S3      Q21 expertise post     5            Expert
## 4       S4      Q21 expertise post     2 Advanced Beginner
## 5       S5      Q21 expertise post     3         Competent
## 6       S6      Q21 expertise post     3         Competent
## 7       S7      Q21 expertise post     4        Proficient
## 8       S8      Q21 expertise post     3         Competent
## 9       S9      Q21 expertise post     1            Novice
## 10     S10      Q21 expertise post     3         Competent
## 11     S11      Q21 expertise post     2 Advanced Beginner
## 12     S12      Q21 expertise post     1            Novice
## 13     S13      Q21 expertise post     3         Competent
```

```
describe(pf_21_pre$score)
```

```
##    vars  n mean   sd median trimmed mad min max range skew kurtosis   se
## X1    1 13 2.15 0.99      2    2.09   0   1   4     3 0.68    -0.64 0.27
```

```
describe(pf_21_post$score)
```

```
##    vars  n mean  sd median trimmed  mad min max range skew kurtosis   se
## X1    1 13 2.54 1.2      3    2.45 1.48   1   5     4 0.32    -0.82 0.33
```

```
t.test(pf_21_post$score, pf_21_pre$score, paired = TRUE)
```

```
##
##  Paired t-test
##
## data:  pf_21_post$score and pf_21_pre$score
## t = 1.6, df = 12, p-value = 0.1
## alternative hypothesis: true mean difference is not equal to 0
## 95 percent confidence interval:
##  -0.1410  0.9102
## sample estimates:
## mean difference
##          0.3846
```

```
# Create the Likert horizontal bar graph for question 19.
# 20, 22, 23, 24

# # Adjust likert datasets to show personal feelings # -
# Very uncomfortable | 1 # - Uncomfortable | 2 # - neutral
# | 3 # - comfortable | 4 # - Very comfortable | 5

pf_all <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_anon_da
View(pf_all)

# Remove q21
pf_all_full <- subset(pf_all, select = c(Q19, Q20, Q22, Q23,
    Q24))
pf_all_full
```

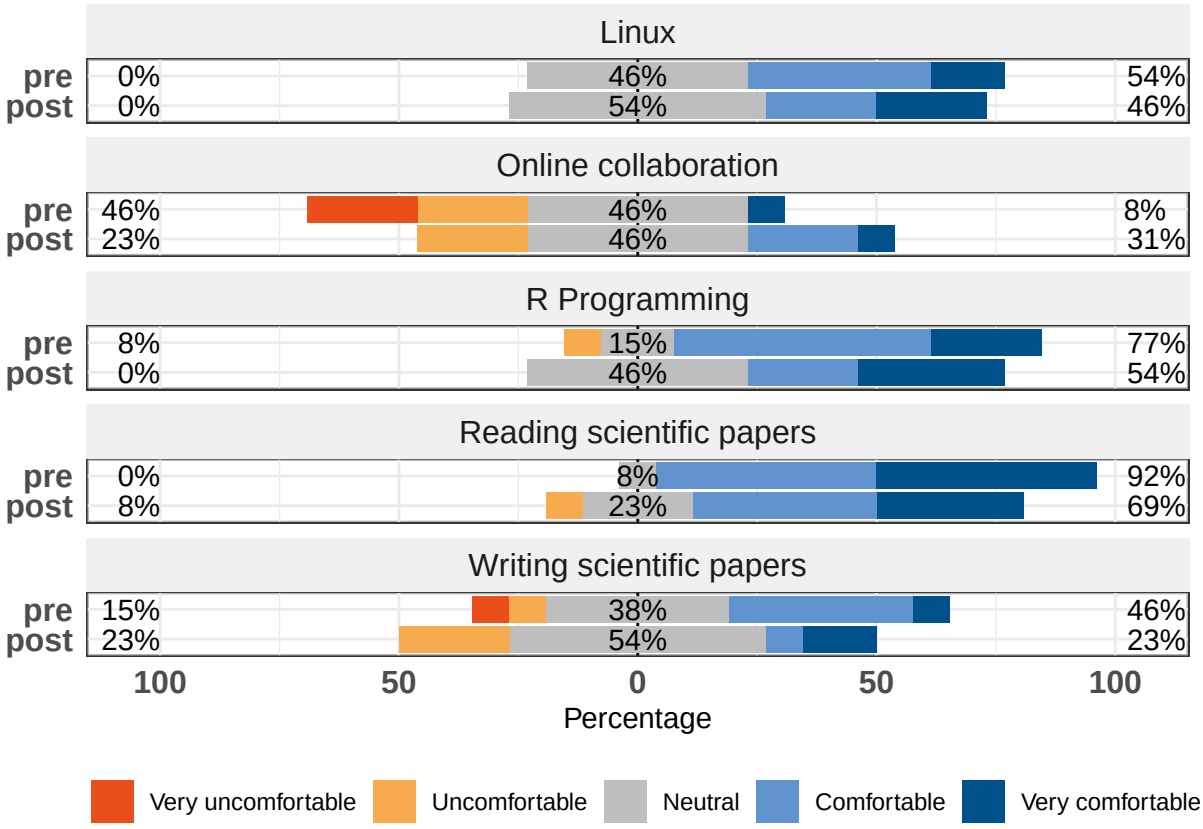
```
##                 Q19                Q20              Q22              Q23
## 1           Neutral Very uncomfortable          Neutral      Comfortable
## 2       Comfortable      Uncomfortable      Comfortable Very comfortable
## 3  Very comfortable            Neutral Very comfortable Very comfortable
## 4           Neutral            Neutral      Comfortable          Neutral
## 5       Comfortable Very uncomfortable          Neutral Very comfortable
## 6           Neutral            Neutral    Uncomfortable      Comfortable
## 7  Very comfortable   Very comfortable      Comfortable Very comfortable
## 8           Neutral      Uncomfortable      Comfortable      Comfortable
## 9       Comfortable      Uncomfortable Very comfortable Very comfortable
## 10      Comfortable            Neutral      Comfortable      Comfortable
## 11          Neutral            Neutral      Comfortable      Comfortable
## 12          Neutral Very uncomfortable      Comfortable      Comfortable
## 13      Comfortable            Neutral Very comfortable Very comfortable
## 14      Comfortable            Neutral          Neutral      Comfortable
## 15          Neutral        Comfortable Very comfortable Very comfortable
## 16 Very comfortable        Comfortable Very comfortable Very comfortable
## 17          Neutral            Neutral      Comfortable          Neutral
## 18      Comfortable            Neutral          Neutral      Comfortable
## 19          Neutral            Neutral          Neutral          Neutral
## 20 Very comfortable   Very comfortable Very comfortable Very comfortable
## 21          Neutral      Uncomfortable          Neutral          Neutral
## 22          Neutral      Uncomfortable      Comfortable      Comfortable
## 23      Comfortable            Neutral          Neutral    Uncomfortable
## 24          Neutral            Neutral          Neutral      Comfortable
## 25          Neutral      Uncomfortable      Comfortable      Comfortable
## 26 Very comfortable        Comfortable Very comfortable Very comfortable
##                  Q24
## 1         Comfortable
## 2         Comfortable
## 3    Very comfortable
## 4       Uncomfortable
## 5         Comfortable
## 6         Comfortable
## 7             Neutral
## 8             Neutral
## 9             Neutral
## 10            Neutral
## 11            Neutral
## 12 Very uncomfortable
## 13        Comfortable
## 14        Comfortable
## 15   Very comfortable
## 16   Very comfortable
## 17            Neutral
## 18            Neutral
## 19            Neutral
## 20            Neutral
## 21      Uncomfortable
## 22            Neutral
## 23      Uncomfortable
## 24            Neutral
## 25      Uncomfortable
## 26            Neutral
```

```
require(likert)

# mylevels <- c('Very uncomfortable', 'Uncomfortable',
# 'Neutral', 'Comfortable', 'Very comfortable')

pf_all_full$Q19 = factor(pf_all_full$Q19, levels = c("Very uncomfortable",
    "Uncomfortable", "Neutral", "Comfortable", "Very comfortable"),
    ordered = TRUE)

pf_all_full$Q20 = factor(pf_all_full$Q20, levels = c("Very uncomfortable",
    "Uncomfortable", "Neutral", "Comfortable", "Very comfortable"),
    ordered = TRUE)

pf_all_full$Q22 = factor(pf_all_full$Q22, levels = c("Very uncomfortable",
    "Uncomfortable", "Neutral", "Comfortable", "Very comfortable"),
    ordered = TRUE)

pf_all_full$Q23 = factor(pf_all_full$Q23, levels = c("Very uncomfortable",
    "Uncomfortable", "Neutral", "Comfortable", "Very comfortable"),
    ordered = TRUE)

pf_all_full$Q24 = factor(pf_all_full$Q24, levels = c("Very uncomfortable",
    "Uncomfortable", "Neutral", "Comfortable", "Very comfortable"),
    ordered = TRUE)
pf_all_full
```

```
##                Q19                Q20              Q22              Q23
## 1          Neutral Very uncomfortable          Neutral      Comfortable
## 2      Comfortable      Uncomfortable      Comfortable Very comfortable
## 3  Very comfortable            Neutral Very comfortable Very comfortable
## 4          Neutral            Neutral      Comfortable          Neutral
## 5      Comfortable Very uncomfortable          Neutral Very comfortable
## 6          Neutral            Neutral    Uncomfortable      Comfortable
## 7  Very comfortable   Very comfortable      Comfortable Very comfortable
## 8          Neutral      Uncomfortable      Comfortable      Comfortable
## 9      Comfortable      Uncomfortable Very comfortable Very comfortable
## 10     Comfortable            Neutral      Comfortable      Comfortable
## 11         Neutral            Neutral      Comfortable      Comfortable
## 12         Neutral Very uncomfortable      Comfortable      Comfortable
## 13     Comfortable            Neutral Very comfortable Very comfortable
## 14     Comfortable            Neutral          Neutral      Comfortable
## 15         Neutral        Comfortable Very comfortable Very comfortable
## 16 Very comfortable        Comfortable Very comfortable Very comfortable
## 17         Neutral            Neutral      Comfortable          Neutral
## 18     Comfortable            Neutral          Neutral      Comfortable
## 19         Neutral            Neutral          Neutral          Neutral
## 20 Very comfortable   Very comfortable Very comfortable Very comfortable
## 21         Neutral      Uncomfortable          Neutral          Neutral
## 22         Neutral      Uncomfortable      Comfortable      Comfortable
## 23     Comfortable            Neutral          Neutral    Uncomfortable
## 24         Neutral            Neutral          Neutral      Comfortable
## 25         Neutral      Uncomfortable      Comfortable      Comfortable
## 26 Very comfortable        Comfortable Very comfortable Very comfortable
```

```
##                   Q24
## 1         Comfortable
## 2         Comfortable
## 3    Very comfortable
## 4       Uncomfortable
## 5         Comfortable
## 6         Comfortable
## 7             Neutral
## 8             Neutral
## 9             Neutral
## 10            Neutral
## 11            Neutral
## 12 Very uncomfortable
## 13        Comfortable
## 14        Comfortable
## 15   Very comfortable
## 16   Very comfortable
## 17            Neutral
## 18            Neutral
## 19            Neutral
## 20            Neutral
## 21      Uncomfortable
## 22            Neutral
## 23      Uncomfortable
## 24            Neutral
## 25      Uncomfortable
## 26            Neutral
```

```
##### Item 24: Reading Attitudes
items2 <- pf_all_full[, substr(names(pf_all), 1, 5) == "Q"]
items2 <- rename(pf_all_full, c(Q19 = "Linux", Q20 = "Online collaboration",
    Q22 = "R Programming", Q23 = "Reading scientific papers",
    Q24 = "Writing scientific papers"))



l2g <- likert(items2[, 1:5], grouping = pf_all$type)
l2g_p <- plot(l2g, as.percent = TRUE, col = c("#E94E1B", "#F7AA4E",
    "#BEBEBE", "#6193CE", "#00508C"), text.size = 4) + theme(strip.text.x = element_text(size = 12),
    legend.position = "bottom", legend.title = element_blank(),
    axis.text = element_text(face = "bold", size = 12), axis.text.y.left = element_text(size = 12))

l2g_p
```




```
# Likert histograms
```

Section 3: What self-reported coping strategies did students use to overcome asynchronous challenges?

Self-reported challenges

```
# Identify the self-reported challenges Create a donut
# chart to view self-reported challenges at a glance

# Upload the counts from each module's self-reported
# challenges
challenges <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_an
    na.strings = "0.00%")
View(challenges)

# Remove totals
challenges_mods <- challenges %>%
    filter(challenges$Module != "Total")

# Copy percent column
challenges_mods = cbind(challenges_mods, replicate(1, challenges_mods$Percent))
```

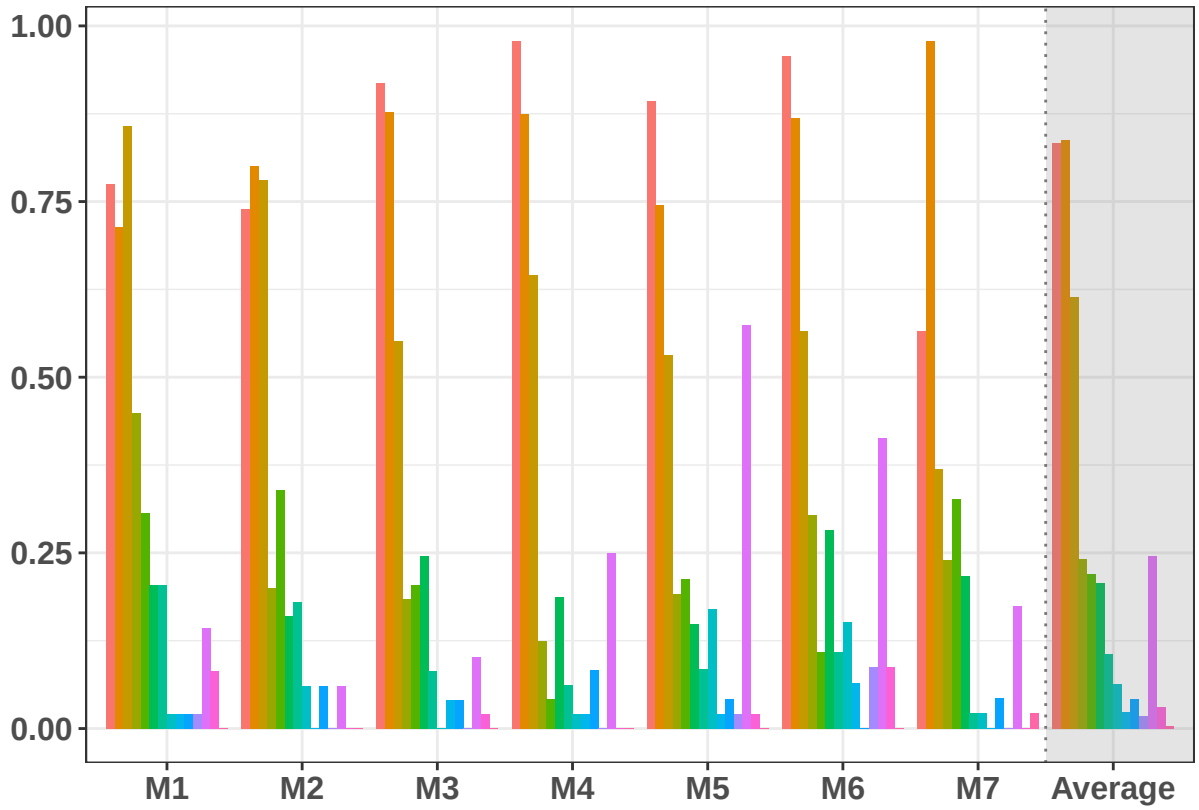
```r
# Rename columns
colnames(challenges_mods)[4] = "Percentage"
colnames(challenges_mods)[5] = "Percent"

# Remove '%' from the percent column challenges_mods %>%
# mutate(Percent = str_replace(Percent, '%', ''))

challenges_mods$Percent <- gsub("%", "", as.character(challenges_mods$Percent))

# Set to numeric
challenges_mods$Percent <- as.numeric(challenges_mods$Percent)

# add the global option for ggrepel to overlap infinity
options(ggrepel.max.overlaps = Inf)

# Donut chart title='Self-reported challenges categorized
# by frequency and module',

chal <- ggplot(challenges_mods, aes(fill = Challenges, y = Percent,
    x = Module)) + # geom_bar(position='fill', stat='identity') + x
    x = Module)) + # geom_bar(position='fill', stat='identity') + =
    x = Module)) + # geom_bar(position='fill', stat='identity') + Module))
    x = Module)) + # geom_bar(position='fill', stat='identity') + +
    x = Module)) + # geom_bar(position='fill', stat='identity') + #
    x = Module)) + # geom_bar(position='fill', stat='identity') + geom_bar(position='fill',
    x = Module)) + # geom_bar(position='fill', stat='identity') + stat='identity')
    x = Module)) + # geom_bar(position='fill', stat='identity') + +
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
geom_col(show.legend = TRUE, color = "white") + # scale_x_discrete(limits = c('M1', 'M2', 'M3', 'M4', '
coord_polar(theta = "y", direction = -1) + geom_text_repel(aes(label = Percentage),
    position = position_stack(vjust = 0.5)) + theme_bw() + labs(y = "Percent reported",
    x = "") + scale_fill_viridis_d() + scale_y_continuous(name = "Percent reported (%)") +
    # geom_vline(xintercept = 7.5, linetype = 3, color =
    # 'grey47') +
theme(legend.title = element_blank(), legend.text = element_text(size = 12),
    legend.position = "bottom", axis.text = element_text(face = "bold",
        size = 12), axis.text.y.left = element_text(size = 12))
```

```
chal


# scale_fill_hue(l=40)

# Challenges Module Count Percent 1 Bio Total 20 10.64% 2
# Coding Total 107 56.91% 3 PD Total 22 11.70% 4 Other
# Total 1 0.53% 5 No challenges Total 8 4.26% 6 Personal
# Total 24 12.77% 7 Cognitive load Total 6 3.19%
```

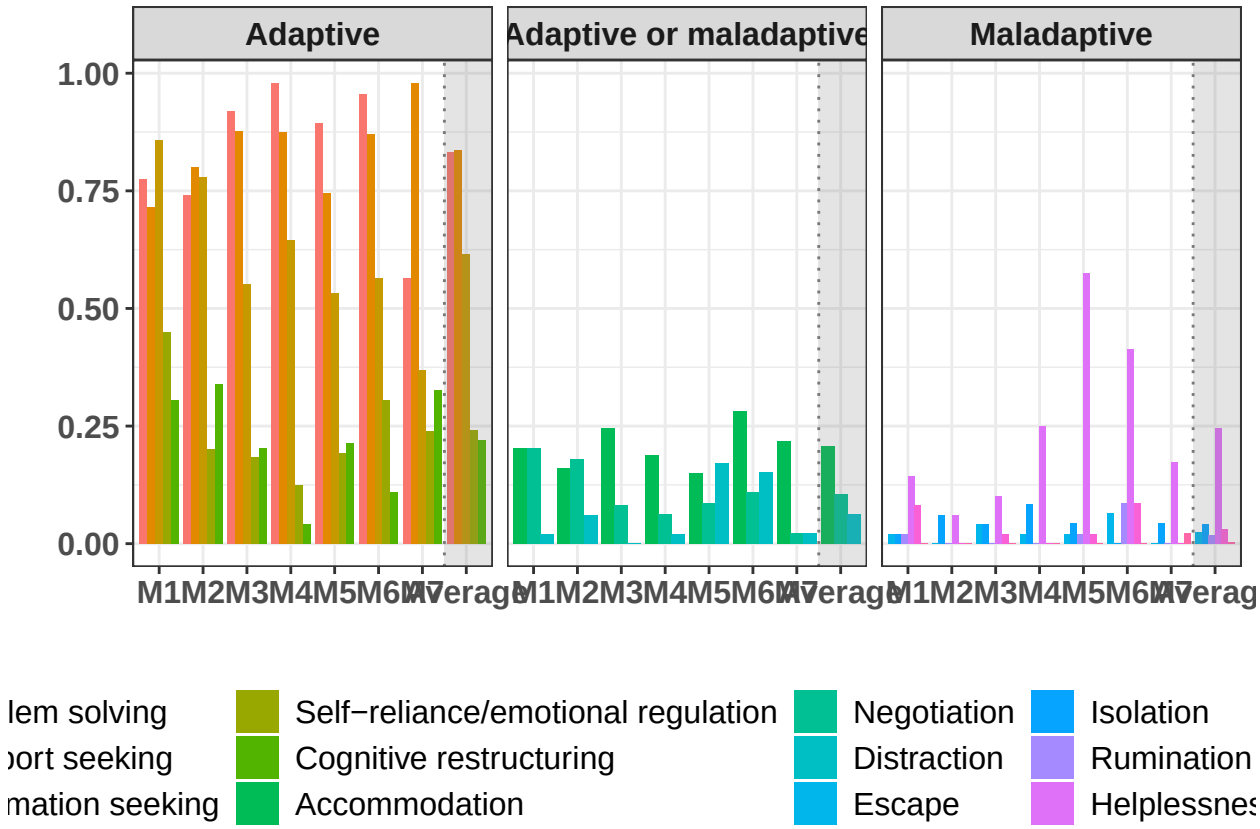
Cognitive Themes

```
# Create a bar plot of reported coping themes and separate
# by adaptive, adaptive or maladaptive, or maladaptive

# Upload the counts from each module's self-reported
# challenges cog_themes <-
# read.csv('C:/Users/splaisie/Dropbox
# (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_anon_datasets/cogthemes.csv')
cog_themes <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_an
View(cog_themes)

# # Optional: Remove totals cog_themes <- cog_themes %>%
# filter(cog_themes$Module != 'Total')

# Expand the color palette to have 14 colors
mycolors2 = c(brewer.pal(name = "Spectral", n = 11), brewer.pal(name = "Dark2",
    n = 3))

# title='Cognitive themes categorized by coping type and
# frequency per module', Add levels to separate each them
# by coping type
cog_themes$Theme = factor(cog_themes$Theme, levels = c("Problem solving",
    "Support seeking", "Information seeking", "Self-reliance/emotional regulation",
    "Cognitive restructuring", "Accommodation", "Negotiation",
    "Distraction", "Escape", "Isolation", "Rumination", "Helplessness",
    "Delegation", "Opposition"))

cog_themes$Module = factor(cog_themes$Module, levels = c("M1",
    "M2", "M3", "M4", "M5", "M6", "M7", "Average"))

# ct <- ggplot(cog_themes, aes(fill=Theme, y=Percentage,
# x=Module), shape = Type) + ct <- ggplot(cog_themes,
# aes(fill=Theme, y=Percentage_SBP, x=Module), shape =
# Type) + ct <- ggplot(cog_themes, aes(fill=Theme,
# y=Proportion_SBP, x=Module), shape = Type) +
ct <- ggplot(cog_themes, aes(fill = Theme, y = Proportion_CCLE_SBP,
    x = Module), shape = Type) + geom_bar(position = "dodge",
    stat = "identity") + annotate("rect", fill = "grey47", alpha = 0.2,
    xmin = 7.5, xmax = Inf, ymin = -Inf, ymax = Inf) + theme(legend.title = element_blank(),
    strip.text.x = element_text(face = "bold", size = 12), legend.text = element_text(size = 12),
    legend.position = "none", axis.text = element_text(face = "bold",
```

```
        size = 12), axis.text.y.left = element_text(size = 12)) +
    labs(y = "Percent reported", x = "") + scale_color_manual(values = mycolors2) +
    scale_y_continuous(name = "") + geom_vline(xintercept = 7.5,
    linetype = 3, color = "grey47")
ct
```




```
ctc <- ct + facet_wrap(Type ~ ., scales = "free_x") + theme(legend.position = "bottom")
ctc
```




```
# ggsave (filename = 'coping_strategies.pdf', plot = ctc,
# height = 5, width = 10) ggsave (filename =
# 'coping_strategies_SBP.pdf', plot = ctc, height = 5,
# width = 10)
ggsave(filename = "coping_strategies_CCLE_SBP.pdf", plot = ctc,
    height = 5, width = 10)
```

Slack analysis

Slack administrators can export analytics that encapsulate the activity of channel members, including # of days active (reading measure) and # of days posting (posting measure). Are these correlated with learning gain? Here, we also investigate Slack engagement versus pre- and post-test scores. Were those with higher pre-test scores more likely to engage on Slack? Were those who had high engagement on Slack more likely to have higher post-test scores?

```
slack <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/Placenta_Fall2022/Analysis/f22B_anon_da
View(slack)

# Normalized learning gain by number of days active on Slack
slack_activity <- ggplot(slack, aes(x = X..active, y = NLG, color = Contribution)) +
  geom_jitter() +
  scale_fill_hue(l=40) +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Percent of Days Active (n = 51)") +
```

```
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="NLG", x = "Percentage of Days Active (n = 51)", fill = "Engagement", color = "Engag
  scale_fill_brewer(palette="Dark2") +
  geom_vline(xintercept=0.5023, linetype=3) +
  geom_hline(yintercept=0.2863, linetype = 3) +
  # annotate("text", x=0.30, y=0.8, label = "Theoretical x =0.5023", size=3, color = "gray47") +
  stat_regline_equation(label.x= 0.70, label.y = 0.15, aes(label = ..eq.label..), size = 3, color ="gray
  stat_regline_equation(label.x = 0.70, label.y = 0.1, aes(label = ..rr.label..), size = 3, color = "gra
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
slack1 = slack_activity + ylim(0,1)

# Normalized learning gain by percentage of channel contribution
slack_convo <- ggplot(slack, aes(x = X..Convo, y = NLG, color = Contribution)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Percent of Days Active (n = 51)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="NLG", x = "Percentage of messages posted", fill = "Engagement", color = "Engagemen
  geom_vline(xintercept=0.0769, linetype=3) +
  geom_hline(yintercept=0.2863, linetype = 3) +
  # annotate("text", x=0.07, y=0.9, label = "Theoretical x =0.0769", size=3, color = "gray47") +
  stat_regline_equation(label.x= 0.2, label.y = 0.15, aes(label = ..eq.label..), size = 3, color ="gray
  stat_regline_equation(label.x = 0.2, label.y = 0.1, aes(label = ..rr.label..), size = 3, color = "gra
slack2 = slack_convo + ylim(0,1)

# Check for significance between student NLGs
cor.test(slack$X..active, slack$NLG, method = "pearson")
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..active and slack$NLG
## t = 1.2, df = 11, p-value = 0.2
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.2525  0.7537
## sample estimates:
##    cor
## 0.3468
```

```
cor.test(slack$X..Convo, slack$NLG, method = "pearson")
```

```
##
```

```
##  Pearson's product-moment correlation
##
## data:  slack$X..Convo and slack$NLG
## t = 4.5, df = 11, p-value = 9e-04
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.4591 0.9397
## sample estimates:
##    cor
## 0.8062
```

```
# Check correlation between Slack analytics and pre-scores/post-scores
# add pre and post scores to the slack dataframe
slack_all <- data.frame(slack,
                        prescore = prescore$score,
                        postscore = postscore$score)

# Pre-scores by number of days active on Slack
slack_activity_pre <- ggplot(slack_all, aes(y = X..active, x = prescore, color = Contribution)) +
  geom_jitter() +
  scale_fill_hue(l=40) +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Percent of Days Active (n = 51)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", x ="Pre-score", y = "Percentage of Days Active (n = 51)", fill = "Engagement", color =
  scale_fill_brewer(palette="Dark2") +
  geom_vline(xintercept=0.5023, linetype=3) +
  geom_hline(yintercept=0.2863, linetype = 3) +
  # annotate("text", x=0.30, y=0.8, label = "Theoretical x =0.5023", size=3, color = "gray47") +
  stat_regline_equation(label.x= 0.70, label.y = 0.15, aes(label = ..eq.label..), size = 3, color ="gra
  stat_regline_equation(label.x = 0.70, label.y = 0.1, aes(label = ..rr.label..), size = 3, color = "gra
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
slack3 = slack_activity_pre + ylim(0,1)


# Pre-scores by percentage of channel contribution
slack_convo_pre <- ggplot(slack_all, aes(y = X..Convo, x = prescore, color = Contribution)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Percent of Days Active (n = 51)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", x ="Pre-score", y = "Percentage of messages posted", fill = "Engagement", color = "Enga
  geom_vline(xintercept=0.0769, linetype=3) +
  geom_hline(yintercept=0.2863, linetype = 3) +
```

```
  # annotate("text", x=0.07, y=0.9, label = "Theoretical x =0.0769", size=3, color = "gray47") +
  stat_regline_equation(label.x= 0.2, label.y = 0.15, aes(label = ..eq.label..), size = 3, color ="gray
  stat_regline_equation(label.x = 0.2, label.y = 0.1, aes(label = ..rr.label..), size = 3, color = "gra
slack4 = slack_convo_pre + ylim(0,1)


# Check correlation of pretest scores for significance
cor.test(slack$X..active, prescore$score, method = "pearson")
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..active and prescore$score
## t = -0.046, df = 11, p-value = 1
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5606  0.5412
## sample estimates:
##      cor
## -0.01395
```

```
cor.test(slack$X..Convo, prescore$score, method = "pearson")
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..Convo and prescore$score
## t = 0.2, df = 11, p-value = 0.8
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.5073  0.5918
## sample estimates:
##     cor
## 0.06057
```

```
# Post-scores by number of days active on Slack
slack_activity_post <- ggplot(slack_all, aes(x = X..active, y = NLG, color = Contribution)) +
  geom_jitter() +
  scale_fill_hue(l=40) +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Percent of Days Active (n = 51)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="Post-score", x = "Percentage of Days Active (n = 51)", fill = "Engagement", color =
  scale_fill_brewer(palette="Dark2") +
  geom_vline(xintercept=0.5023, linetype=3) +
  geom_hline(yintercept=0.2863, linetype = 3) +
  # annotate("text", x=0.30, y=0.8, label = "Theoretical x =0.5023", size=3, color = "gray47") +
  stat_regline_equation(label.x= 0.70, label.y = 0.15, aes(label = ..eq.label..), size = 3, color ="gra
  stat_regline_equation(label.x = 0.70, label.y = 0.1, aes(label = ..rr.label..), size = 3, color = "gra
```

```
## Scale for fill is already present.
## Adding another scale for fill, which will replace the existing scale.
```

```
slack5 = slack_activity_post + ylim(0,1)

# Post-scores by percentage of channel contribution
slack_convo_post <- ggplot(slack_all, aes(x = X..Convo, y = postscore, color = Contribution)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Percent of Days Active (n = 51)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="Post-score", x = "Percentage of messages posted", fill = "Engagement", color = "Eng
  geom_vline(xintercept=0.0769, linetype=3) +
  geom_hline(yintercept=0.2863, linetype = 3) +
  # annotate("text", x=0.07, y=0.9, label = "Theoretical x =0.0769", size=3, color = "gray47") +
  stat_regline_equation(label.x= 0.2, label.y = 0.15, aes(label = ..eq.label..), size = 3, color ="gray
  stat_regline_equation(label.x = 0.2, label.y = 0.1, aes(label = ..rr.label..), size = 3, color = "gra
slack6 = slack_convo_post + ylim(0,1)

# Check posttest scores
cor.test(slack$X..active, postscore$score, method = "pearson")
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..active and postscore$score
## t = 0.98, df = 11, p-value = 0.3
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.3160  0.7223
## sample estimates:
##    cor
## 0.2845
```

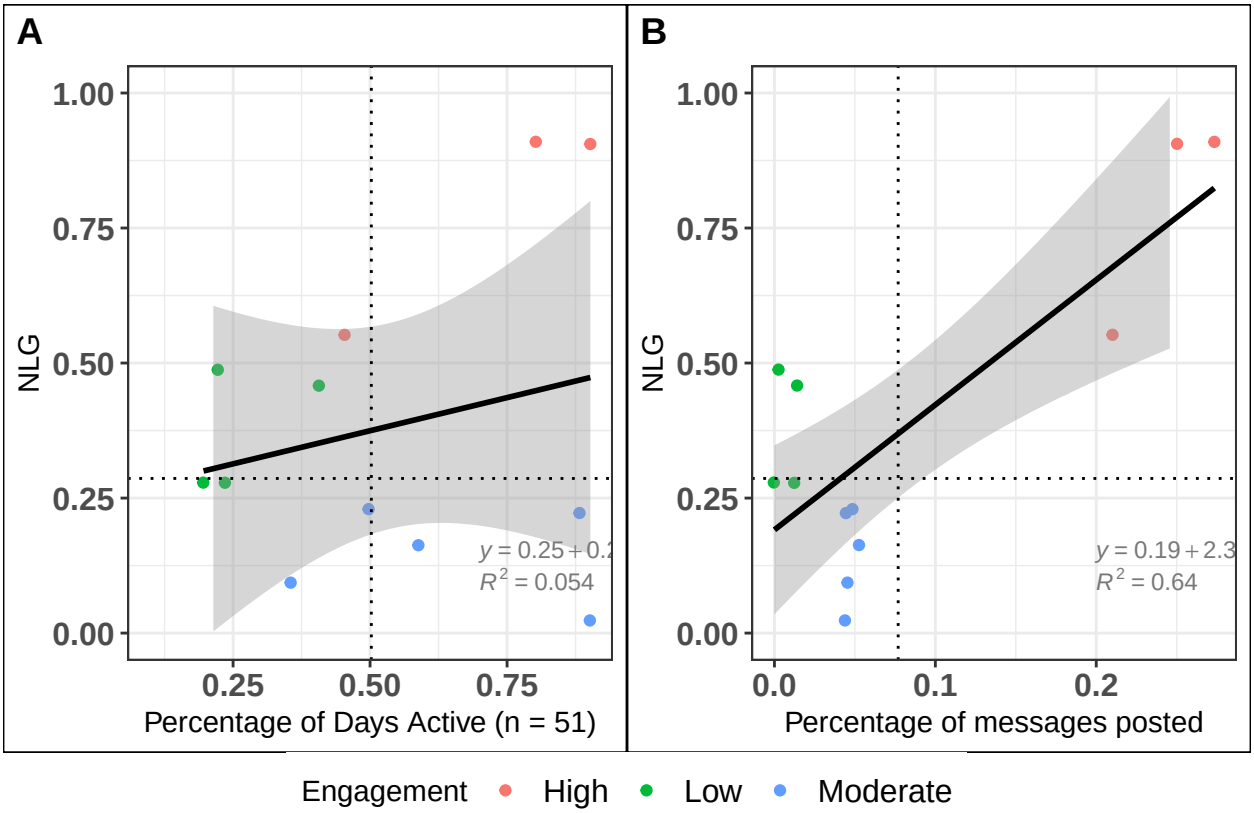
```
cor.test(slack$X..Convo, postscore$score, method = "pearson")
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..Convo and postscore$score
## t = 2.5, df = 11, p-value = 0.03
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.08421 0.86778
## sample estimates:
##   cor
## 0.607
```

```r
# Use ggarrange to create a panel for both A. and B.
# library(ggpubr) #load in library for multi-panel figures
# put all three plots together into one multipanel plot
multi_plot_NLG <- ggarrange(slack1, slack2, #plots that are going to be included in this multipanel fig
                        labels = c("A", "B"), #labels given each panel
                        ncol = 2, nrow = 1, #adjust plot space
                        common.legend = T,
                        legend = "bottom")
```

```
## Warning: The dot-dot notation (`..eq.label..`) was deprecated in ggplot2 3.4.0.
## i Please use `after_stat(eq.label)` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.

## `geom_smooth()` using formula = 'y ~ x'

## Warning: Removed 1 rows containing non-finite values (`stat_smooth()`).

## Warning: Removed 1 rows containing non-finite values (`stat_regline_equation()`).
## Removed 1 rows containing non-finite values (`stat_regline_equation()`).

## Warning: Removed 1 rows containing missing values (`geom_point()`).

## `geom_smooth()` using formula = 'y ~ x'

## Warning: Removed 1 rows containing non-finite values (`stat_smooth()`).

## Warning: Removed 1 rows containing non-finite values (`stat_regline_equation()`).
## Removed 1 rows containing non-finite values (`stat_regline_equation()`).

## Warning: Removed 1 rows containing missing values (`geom_point()`).

## `geom_smooth()` using formula = 'y ~ x'

## Warning: Removed 1 rows containing non-finite values (`stat_smooth()`).

## Warning: Removed 1 rows containing non-finite values (`stat_regline_equation()`).
## Removed 1 rows containing non-finite values (`stat_regline_equation()`).

## Warning: Removed 1 rows containing missing values (`geom_point()`).
```

```r
#does the plot have a common legend
#add titles and labels to the multi-panel graph
multi_plot_NLG <- annotate_figure(multi_plot_NLG,
                              top = text_grob("", color = "black", face = "bold", size = 11)) + scale_f
multi_plot_NLG
```




```
ggsave(filename = "Slack_NLG.pdf", plot = multi_plot_NLG, height = 4, width = 8)

# Check for Pearson's correlation coefficient
cor.test(slack$X..active,slack$NLG)
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..active and slack$NLG
## t = 1.2, df = 11, p-value = 0.2
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.2525  0.7537
## sample estimates:
##    cor
## 0.3468
```

```
# [1] 0.3468
cor.test(slack$X..Convo,slack$NLG)
```

```
##
##  Pearson's product-moment correlation
##
## data:  slack$X..Convo and slack$NLG
## t = 4.5, df = 11, p-value = 9e-04
```

```
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.4591 0.9397
## sample estimates:
##    cor
## 0.8062
```

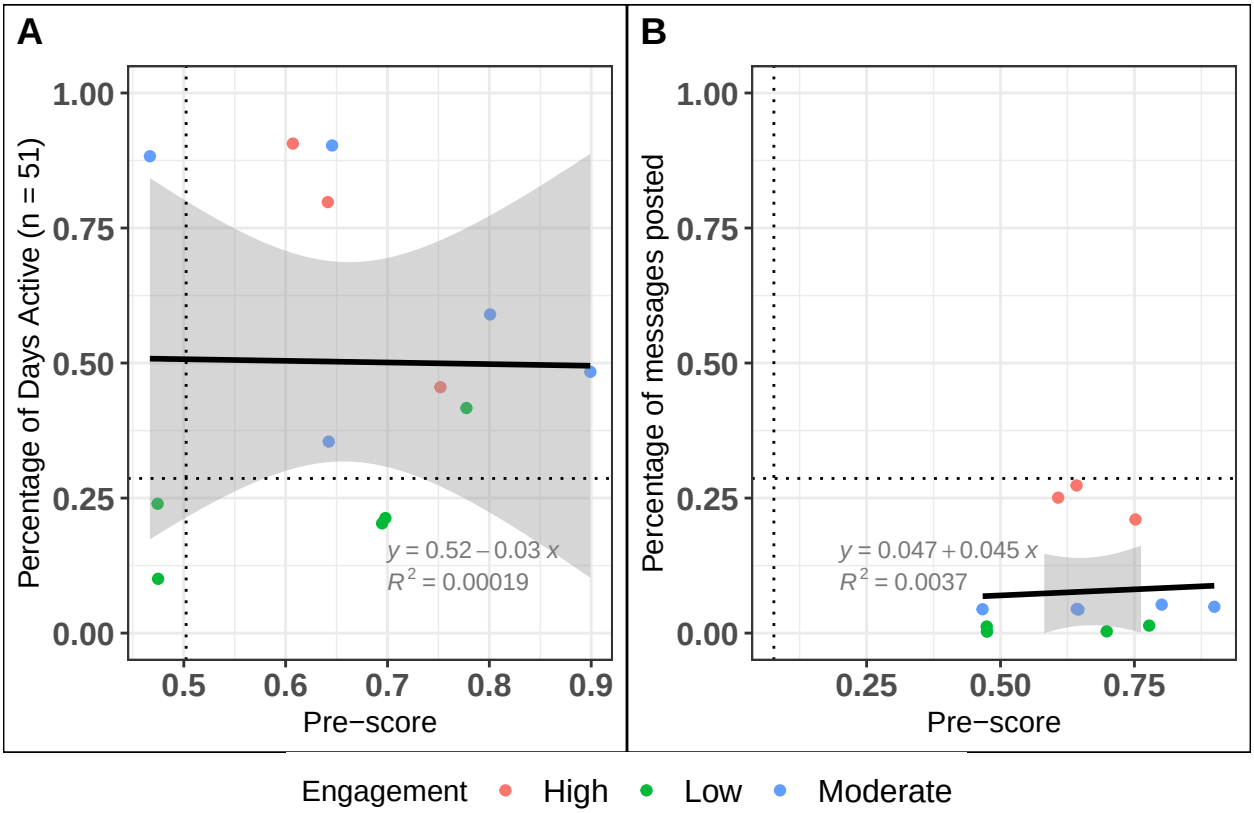
```
# [1] 0.8062


# Use ggarrange to create a panel for both A. and B.
# library(ggpubr) #load in library for multi-panel figures
# put all three plots together into one multipanel plot
multi_plot_pre <- ggarrange(slack3, slack4, #plots that are going to be included in this multipanel fig
                        labels = c("A", "B"), #labels given each panel
                        ncol = 2, nrow = 1, #adjust plot space
                        common.legend = T,
                        legend = "bottom")
```

```
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
```

```
## Warning: Removed 1 rows containing missing values (`geom_point()`).
```

```
# does the plot have a common legend
# add titles and labels to the multi-panel graph
multi_plot_pre <- annotate_figure(multi_plot_pre,
                              top = text_grob("", color = "black", face = "bold", size = 11)) + scale_f
multi_plot_pre
```




```
# Use ggarrange to create a panel for both A. and B.
# library(ggpubr) #load in library for multi-panel figures
# put all three plots together into one multipanel plot
multi_plot_post <- ggarrange(slack5, slack6, #plots that are going to be included in this multipanel fi
                        labels = c("A", "B"), #labels given each panel
                        ncol = 2, nrow = 1, #adjust plot space
                        common.legend = T,
                        legend = "bottom")
```

```
## `geom_smooth()` using formula = 'y ~ x'

## Warning: Removed 1 rows containing non-finite values (`stat_smooth()`).

## Warning: Removed 1 rows containing non-finite values (`stat_regline_equation()`).
## Removed 1 rows containing non-finite values (`stat_regline_equation()`).

## Warning: Removed 1 rows containing missing values (`geom_point()`).

## `geom_smooth()` using formula = 'y ~ x'

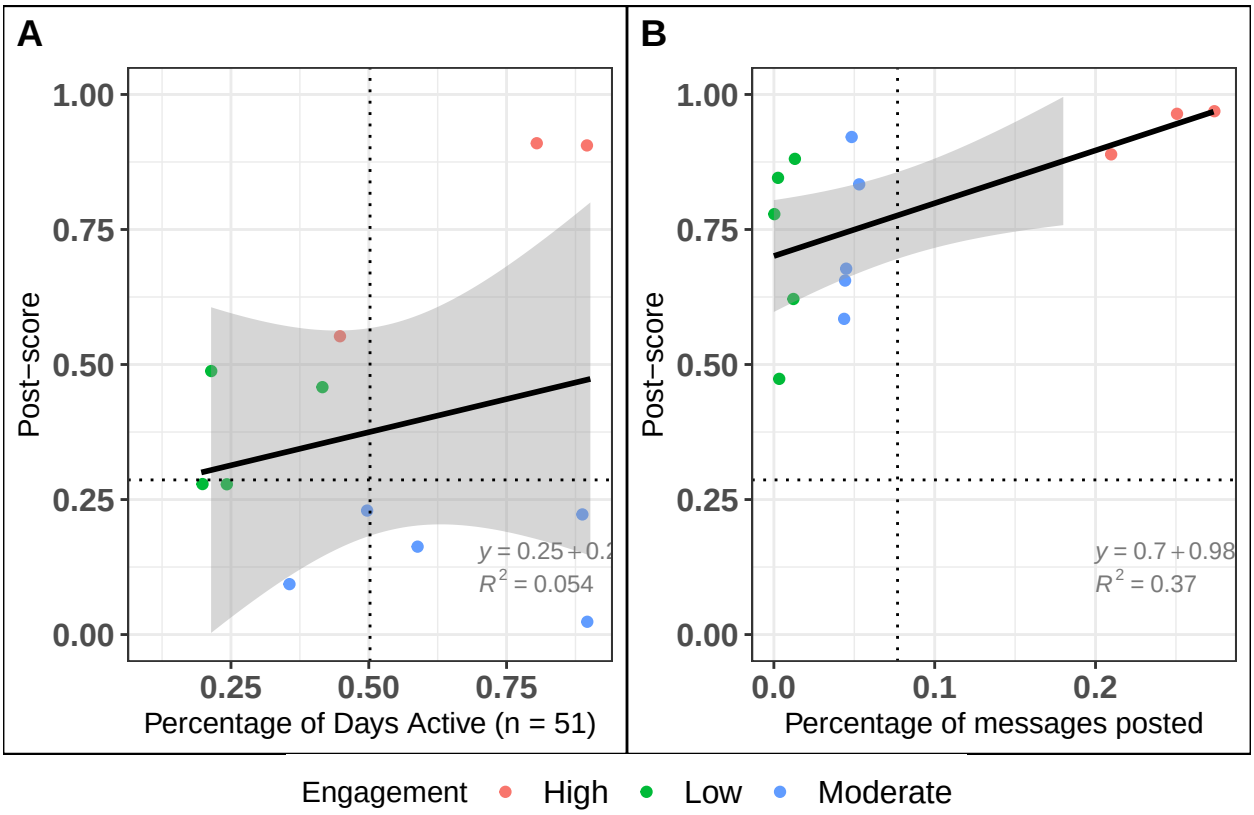
## Warning: Removed 1 rows containing non-finite values (`stat_smooth()`).

## Warning: Removed 1 rows containing non-finite values (`stat_regline_equation()`).
## Removed 1 rows containing non-finite values (`stat_regline_equation()`).
```

```
## Warning: Removed 1 rows containing missing values (`geom_point()`).
```

```
## `geom_smooth()` using formula = 'y ~ x'
```

```
#does the plot have a common legend
#add titles and labels to the multi-panel graph
multi_plot_post <- annotate_figure(multi_plot_post,
                                   top = text_grob("", color = "black", face = "bold", size = 11)) + scale_f
multi_plot_post
```




```
# Days active vs Pre-Post score
CURE1_daysactive = ggplot(slack, aes(x = Days.active, y = Score_change)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Days Active (Iteration 1)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="POST - PRE score", x = "Days active")

CURE1_messagesposted = ggplot(slack, aes(x = Messages.posted, y = Score_change)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Messages posted (Iteration 1)") +
```

```
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="POST - PRE score", x = "Messages posted")


CURE1_slack_multi <- ggarrange(CURE1_daysactive, CURE1_messagesposted, #plots that are going to be incl
                        labels = c("A", "B"), #labels given each panel
                        ncol = 2, nrow = 1, #adjust plot space
                        common.legend = T,
                        legend = "bottom")
```

```
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
```

```
ggsave("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/CCLE_Fall2023/slack_analytics/slack_prepost_scatte


slack_CCLE <- read.csv("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/CCLE_Fall2023/slack_analytics/2023

CURE2_daysactive = ggplot(slack_CCLE, aes(x = Days.active, y = Post.Pre)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Days Active (Iteration 2)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="POST - PRE score", x = "Days active")

CURE2_messagesposted = ggplot(slack_CCLE, aes(x = Messages.posted, y = Post.Pre)) +
  geom_jitter() +
  geom_smooth(method=lm , color="black",se=T) +
  xlab("Messages posted (Iteration 2)") +
  theme(legend.text=element_text(size=12),
        legend.position = "right",
        axis.text = element_text(face="bold", size = 12),
        axis.text.y.left = element_text(size = 12), plot.background = element_rect(color = "black")) +
  labs(title="", y ="POST - PRE score", x = "Messages posted")

CURE2_slack_multi <- ggarrange(CURE2_daysactive, CURE2_messagesposted, #plots that are going to be incl
                        labels = c("A", "B"), #labels given each panel
                        ncol = 2, nrow = 1, #adjust plot space
                        common.legend = T,
                        legend = "bottom")
```

```
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
## `geom_smooth()` using formula = 'y ~ x'
```

```
ggsave("C:/Users/splaisie/Dropbox (ASU)/GenomicsCURE/CCLE_Fall2023/slack_analytics/slack_prepost_scatte
```

```
session_info()
```

```
## - Session info ---------------------------------------------------------------
##  setting  value
##  version  R version 4.2.1 (2022-06-23 ucrt)
##  os       Windows 10 x64 (build 19044)
##  system   x86_64, mingw32
##  ui       RTerm
##  language (EN)
##  collate  English_United States.utf8
##  ctype    English_United States.utf8
##  tz       America/Phoenix
##  date     2024-04-12
##  pandoc   2.17.1.1 @ C:/Program Files/RStudio/bin/quarto/bin/ (via rmarkdown)
##
## - Packages -------------------------------------------------------------------
##  package      * version   date (UTC) lib source
##  abind          1.4-5     2016-07-21 [1] CRAN (R 4.2.0)
##  backports      1.4.1     2021-12-13 [1] CRAN (R 4.2.0)
##  betareg      * 3.1-4     2021-02-09 [1] CRAN (R 4.2.3)
##  bit            4.0.5     2022-11-15 [1] CRAN (R 4.2.2)
##  bit64          4.0.5     2020-08-30 [1] CRAN (R 4.2.0)
##  broom          1.0.5     2023-06-09 [1] CRAN (R 4.2.3)
##  cachem         1.0.8     2023-05-01 [1] CRAN (R 4.2.3)
##  car            3.1-2     2023-03-30 [1] CRAN (R 4.2.3)
##  carData        3.0-5     2022-01-06 [1] CRAN (R 4.2.0)
##  class          7.3-22    2023-05-03 [1] CRAN (R 4.2.3)
##  cli            3.6.1     2023-03-23 [1] CRAN (R 4.2.3)
##  colorspace     2.1-0     2023-01-23 [1] CRAN (R 4.2.2)
##  cowplot        1.1.3     2024-01-22 [1] CRAN (R 4.2.3)
##  crayon         1.5.2     2022-09-29 [1] CRAN (R 4.2.1)
##  curl           5.2.0     2023-12-08 [1] CRAN (R 4.2.3)
##  data.table   * 1.14.10   2023-12-08 [1] CRAN (R 4.2.3)
##  devtools     * 2.4.5     2022-10-11 [1] CRAN (R 4.2.3)
##  digest         0.6.33    2023-07-07 [1] CRAN (R 4.2.3)
##  dplyr        * 1.1.4     2023-11-17 [1] CRAN (R 4.2.3)
##  e1071          1.7-14    2023-12-06 [1] CRAN (R 4.2.3)
##  effsize      * 0.8.1     2020-10-05 [1] CRAN (R 4.2.3)
##  ellipsis       0.3.2     2021-04-29 [1] CRAN (R 4.2.0)
##  evaluate       0.23      2023-11-01 [1] CRAN (R 4.2.3)
##  fansi          1.0.6     2023-12-08 [1] CRAN (R 4.2.3)
##  farver         2.1.1     2022-07-06 [1] CRAN (R 4.2.1)
##  fastmap        1.1.1     2023-02-24 [1] CRAN (R 4.2.3)
##  fitdistrplus * 1.1-11    2023-04-25 [1] CRAN (R 4.2.3)
##  flexmix        2.3-19    2023-03-16 [1] CRAN (R 4.2.3)
##  forcats      * 1.0.0     2023-01-29 [1] CRAN (R 4.2.2)
##  formatR        1.14      2023-01-17 [1] CRAN (R 4.2.2)
##  Formula        1.2-5     2023-02-24 [1] CRAN (R 4.2.2)
##  fs             1.6.3     2023-07-20 [1] CRAN (R 4.2.3)
##  generics       0.1.3     2022-07-05 [1] CRAN (R 4.2.1)
##  ggplot2      * 3.4.4     2023-10-12 [1] CRAN (R 4.2.3)
```

```
##  ggpmisc      * 0.5.5     2023-11-15 [1] CRAN (R 4.2.3)
##  ggpp         * 0.5.6     2024-01-09 [1] CRAN (R 4.2.3)
##  ggpubr       * 0.6.0.999 2024-02-10 [1] Github (kassambara/ggpubr@6aeb4f7)
##  ggrepel      * 0.9.5     2024-01-10 [1] CRAN (R 4.2.1)
##  ggsci          3.0.0     2023-03-08 [1] CRAN (R 4.2.3)
##  ggsignif       0.6.4     2022-10-13 [1] CRAN (R 4.2.1)
##  gld          * 2.6.6     2022-10-23 [1] CRAN (R 4.2.3)
##  glue           1.6.2     2022-02-24 [1] CRAN (R 4.2.0)
##  gridExtra    * 2.3       2017-09-09 [1] CRAN (R 4.2.0)
##  gtable         0.3.4     2023-08-21 [1] CRAN (R 4.2.3)
##  highr          0.10      2022-12-22 [1] CRAN (R 4.2.2)
##  hms            1.1.3     2023-03-21 [1] CRAN (R 4.2.3)
##  htmltools      0.5.7     2023-11-03 [1] CRAN (R 4.2.3)
##  htmlwidgets    1.6.4     2023-12-06 [1] CRAN (R 4.2.3)
##  httpuv         1.6.14    2024-01-26 [1] CRAN (R 4.2.3)
##  knitr        * 1.45      2023-10-30 [1] CRAN (R 4.2.3)
##  labeling       0.4.3     2023-08-29 [1] CRAN (R 4.2.3)
##  later          1.3.2     2023-12-06 [1] CRAN (R 4.2.3)
##  lattice      * 0.22-5    2023-10-24 [1] CRAN (R 4.2.3)
##  lifecycle      1.0.4     2023-11-07 [1] CRAN (R 4.2.3)
##  likert       * 1.3.5     2016-12-31 [1] CRAN (R 4.2.3)
##  lmom           3.0       2023-08-29 [1] CRAN (R 4.2.3)
##  lmtest         0.9-40    2022-03-21 [1] CRAN (R 4.2.2)
##  logspline    * 2.1.21    2023-10-26 [1] CRAN (R 4.2.3)
##  lubridate    * 1.9.3     2023-09-27 [1] CRAN (R 4.2.3)
##  magrittr       2.0.3     2022-03-30 [1] CRAN (R 4.2.0)
##  MASS         * 7.3-60    2023-05-04 [1] CRAN (R 4.2.3)
##  Matrix         1.6-4     2023-11-30 [1] CRAN (R 4.2.3)
##  MatrixModels   0.5-3     2023-11-06 [1] CRAN (R 4.2.3)
##  matrixStats    1.1.0     2023-11-07 [1] CRAN (R 4.2.1)
##  matrixTests  * 0.2.3     2023-10-05 [1] CRAN (R 4.2.1)
##  memoise        2.0.1     2021-11-26 [1] CRAN (R 4.2.0)
##  mgcv           1.9-1     2023-12-21 [1] CRAN (R 4.2.3)
##  mime           0.12      2021-09-28 [1] CRAN (R 4.2.0)
##  miniUI         0.1.1.1   2018-05-18 [1] CRAN (R 4.2.2)
##  mnormt         2.1.1     2022-09-26 [1] CRAN (R 4.2.1)
##  modeltools     0.2-23    2020-03-05 [1] CRAN (R 4.2.0)
##  munsell        0.5.0     2018-06-12 [1] CRAN (R 4.2.0)
##  mvtnorm      * 1.2-4     2023-11-27 [1] CRAN (R 4.2.3)
##  nlme           3.1-164   2023-11-27 [1] CRAN (R 4.2.3)
##  nnet           7.3-19    2023-05-03 [1] CRAN (R 4.2.3)
##  PairedData   * 1.1.1     2018-06-02 [1] CRAN (R 4.2.3)
##  pillar         1.9.0     2023-03-22 [1] CRAN (R 4.2.3)
##  pkgbuild       1.4.3     2023-12-10 [1] CRAN (R 4.2.3)
##  pkgconfig      2.0.3     2019-09-22 [1] CRAN (R 4.2.0)
##  pkgload        1.3.4     2024-01-16 [1] CRAN (R 4.2.3)
##  plyr         * 1.8.9     2023-10-02 [1] CRAN (R 4.2.3)
##  polynom        1.4-1     2022-04-11 [1] CRAN (R 4.2.0)
##  profvis        0.3.8     2023-05-02 [1] CRAN (R 4.2.3)
##  promises       1.2.1     2023-08-10 [1] CRAN (R 4.2.3)
##  proxy          0.4-27    2022-06-09 [1] CRAN (R 4.2.1)
##  psych        * 2.4.1     2024-01-18 [1] CRAN (R 4.2.3)
##  purrr        * 1.0.2     2023-08-10 [1] CRAN (R 4.2.3)
##  quantreg       5.97      2023-08-19 [1] CRAN (R 4.2.3)
```

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##  R              2.5.1     2021-08-19 [1] CRAN (R 4.2.0)
##  ragg           1.2.7     2023-12-11 [1] CRAN (R 4.2.3)
##  RColorBrewer * 1.1-3     2022-04-03 [1] CRAN (R 4.2.0)
##  Rcpp           1.0.11    2023-07-06 [1] CRAN (R 4.2.3)
##  readr        * 2.1.5     2024-01-10 [1] CRAN (R 4.2.1)
##  remotes        2.4.2.1   2023-07-18 [1] CRAN (R 4.2.3)
##  reshape2       1.4.4     2020-04-09 [1] CRAN (R 4.2.2)
##  rlang          1.1.1     2023-04-28 [1] CRAN (R 4.2.3)
##  rmarkdown      2.25      2023-09-18 [1] CRAN (R 4.2.3)
##  rstatix        0.7.2     2023-02-01 [1] CRAN (R 4.2.2)
##  rstudioapi     0.15.0    2023-07-07 [1] CRAN (R 4.2.3)
##  sandwich       3.1-0     2023-12-11 [1] CRAN (R 4.2.3)
##  scales         1.3.0     2023-11-28 [1] CRAN (R 4.2.3)
##  sessioninfo    1.2.2     2021-12-06 [1] CRAN (R 4.2.3)
##  shiny          1.8.0     2023-11-17 [1] CRAN (R 4.2.3)
##  SparseM        1.81      2021-02-18 [1] CRAN (R 4.2.0)
##  stringi        1.8.3     2023-12-11 [1] CRAN (R 4.2.3)
##  stringr      * 1.5.1     2023-11-14 [1] CRAN (R 4.2.3)
##  survival     * 3.5-7     2023-08-14 [1] CRAN (R 4.2.3)
##  systemfonts    1.0.5     2023-10-09 [1] CRAN (R 4.2.3)
##  textshaping    0.3.7     2023-10-09 [1] CRAN (R 4.2.3)
##  tibble       * 3.2.1     2023-03-20 [1] CRAN (R 4.2.3)
##  tidyr        * 1.3.0     2023-01-24 [1] CRAN (R 4.2.3)
##  tidyselect     1.2.0     2022-10-10 [1] CRAN (R 4.2.3)
##  tidyverse    * 2.0.0     2023-02-22 [1] CRAN (R 4.2.3)
##  timechange     0.2.0     2023-01-11 [1] CRAN (R 4.2.2)
##  tinytex      * 0.49      2023-11-22 [1] CRAN (R 4.2.3)
##  tzdb           0.4.0     2023-05-12 [1] CRAN (R 4.2.3)
##  urlchecker     1.0.1     2021-11-30 [1] CRAN (R 4.2.3)
##  usethis      * 2.2.2     2023-07-06 [1] CRAN (R 4.2.3)
##  utf8           1.2.4     2023-10-22 [1] CRAN (R 4.2.3)
##  vctrs          0.6.5     2023-12-01 [1] CRAN (R 4.2.3)
##  vroom          1.6.5     2023-12-05 [1] CRAN (R 4.2.3)
##  withr          3.0.0     2024-01-16 [1] CRAN (R 4.2.3)
##  xfun           0.40      2023-08-09 [1] CRAN (R 4.2.3)
##  xtable       * 1.8-4     2019-04-21 [1] CRAN (R 4.2.0)
##  yaml           2.3.7     2023-01-23 [1] CRAN (R 4.2.3)
##  zoo            1.8-12    2023-04-13 [1] CRAN (R 4.2.3)
##
##  [1] C:/Users/splaisie/AppData/Local/R/win-library/4.2
##  [2] C:/Program Files/R/R-4.2.1/library
##
## ------------------------------------------------------------------------------
```