Student Engagement and Performance Segmentation

```
student_performance <- read.csv("../Data/TUMO Yerevan_Students Performance_Table - Sheet1.csv")
```

```
str(student_performance)
```

```
## 'data.frame':    10139 obs. of  14 variables:
##  $ TumoID                : num  2.41e+11 2.41e+11 2.31e+11 2.30e+11 2.50e+11 ...
##  $ Age                   : int  14 13 14 14 13 13 13 15 20 14 ...
##  $ Classification        : chr  "T" "T" "M" "M" ...
##  $ Schedule              : chr  "Sunday 13:30" "Monday 17:30" "Sunday 13:30" "Tuesday 19:30" ...
##  $ Status                : chr  "Active" "Preclosed" "Active" "Active" ...
##  $ RetentionGrouped      : chr  "0.5 - 1 Year" "0.1 - 0.5 Year" "1.5 - 2 Year" "2 - 2.5 Year" ...
##  $ Awarded               : int  38 8 36 35 12 13 19 20 22 52 ...
##  $ Rejected              : int  6 0 4 2 4 2 1 3 0 1 ...
##  $ Completed             : int  1 0 5 4 0 0 1 2 0 6 ...
##  $ Incomplete            : int  0 0 0 2 0 0 0 0 0 1 ...
##  $ Participated          : int  0 0 0 0 0 1 2 0 0 0 ...
##  $ Withdrawn             : int  0 0 0 2 0 0 0 0 1 1 ...
##  $ LearningLabs.Completed: int  0 0 1 2 0 0 0 0 0 0 ...
##  $ AttendingSince        : chr  "10/10/2024" "2/10/2025" "12/7/2023" "6/6/2023" ...
```

```
student_info <- read.csv("../Data/TUMO Yerevan Center Report_Students List_Table - Sheet1.csv", colClass
str(student_info) #
```

```
## 'data.frame':    10428 obs. of  11 variables:
##  $ TumoID           : chr  "2.30326E+11" "2.30113E+11" "2.40401E+11" "2.50414E+11" ...
##  $ BirthDate        : chr  "11-Jul-10" "9-Nov-10" "20-Mar-12" "29-Jan-13" ...
##  $ Classification   : chr  "M" "U" "T" "T" ...
##  $ Status           : chr  "Active" "Active" "Active" "Active" ...
##  $ StudentSchedule  : chr  "Sunday 13:30" "Friday 17:30" "Wednesday 15:30" "Wednesday 19:30" ...
##  $ AttendingSince   : chr  "14-Sep-23" "12-Apr-23" "5-Jun-24" "7-May-25" ...
##  $ RetentionByMonths: int  22 27 13 2 27 21 18 6 6 8 ...
##  $ RetentionGrouped : chr  "1.5 - 2 Year" "2 - 2.5 Year" "1 - 1.5 Year" "0.1 - 0.5 Year" ...
##  $ Age              : int  15 14 13 12 14 15 14 14 12 12 ...
##  $ Present          : chr  "109" "120" "64" "13" ...
##  $ PresenceRatio    : chr  "85" "90" "86" "81" ...
```

```
student_info$TumoID <- as.numeric(student_info$TumoID)
options(scipen = 999)
```

```
student_performance$task_rating <- round(student_performance$Awarded /
      (student_performance$Awarded + student_performance$Rejected), 2)

student_performance$training_rating <- round(student_performance$Completed /
      (student_performance$Incomplete + student_performance$Participated +
         student_performance$Withdrawn + student_performance$Completed), 2)
```

```r
str(student_performance)
```

```
## 'data.frame':    10139 obs. of  16 variables:
##  $ TumoID                : num  240712000018 240924000012 230619000016 230121000032 250415000009 ...
##  $ Age                   : int  14 13 14 14 13 13 13 15 20 14 ...
##  $ Classification        : chr  "T" "T" "M" "M" ...
##  $ Schedule              : chr  "Sunday 13:30" "Monday 17:30" "Sunday 13:30" "Tuesday 19:30" ...
##  $ Status                : chr  "Active" "Preclosed" "Active" "Active" ...
##  $ RetentionGrouped      : chr  "0.5 - 1 Year" "0.1 - 0.5 Year" "1.5 - 2 Year" "2 - 2.5 Year" ...
##  $ Awarded               : int  38 8 36 35 12 13 19 20 22 52 ...
##  $ Rejected              : int  6 0 4 2 4 2 1 3 0 1 ...
##  $ Completed             : int  1 0 5 4 0 0 1 2 0 6 ...
##  $ Incomplete            : int  0 0 0 2 0 0 0 0 0 1 ...
##  $ Participated          : int  0 0 0 0 0 1 2 0 0 0 ...
##  $ Withdrawn             : int  0 0 0 2 0 0 0 0 1 1 ...
##  $ LearningLabs.Completed: int  0 0 1 2 0 0 0 0 0 0 ...
##  $ AttendingSince        : chr  "10/10/2024" "2/10/2025" "12/7/2023" "6/6/2023" ...
##  $ task_rating           : num  0.86 1 0.9 0.95 0.75 0.87 0.95 0.87 1 0.98 ...
##  $ training_rating       : num  1 NaN 1 0.5 NaN 0 0.33 1 0 0.75 ...
```

```r
table(student_performance$task_rating)
```

```
##
## 0.36  0.5 0.52 0.53 0.54 0.57 0.58 0.59  0.6 0.61 0.62 0.63 0.64 0.65 0.67 0.68
##    1    1    1    1    2    4    4    2    4    1    6    4    6   17   14   14
## 0.69  0.7 0.71 0.72 0.73 0.74 0.75 0.76 0.77 0.78 0.79  0.8 0.81 0.82 0.83 0.84
##   23   21   30   23   28   38   53   54   57   77   96   89  108  128  144  113
## 0.85 0.86 0.87 0.88 0.89  0.9 0.91 0.92 0.93 0.94 0.95 0.96 0.97 0.98 0.99    1
##  182  236  167  352  331  392  384  472  534  631  727  776  793  682  150 2166
```

```r
table(student_performance$training_rating)
```

```
##
##    0 0.08 0.09  0.1 0.11 0.12 0.13 0.14 0.17 0.18  0.2 0.21 0.22 0.23 0.25 0.27
##  946    6    5    4    8   17    1   27   38    9   75    3   17    6  190    7
## 0.28 0.29  0.3 0.31 0.32 0.33 0.35 0.36 0.37 0.38 0.39  0.4 0.41 0.42 0.43 0.44
##    1   61   26    4    2  365    2   20    1   54    2  181    2   11   68   42
## 0.45 0.46 0.47 0.48  0.5 0.52 0.53 0.54 0.55 0.56 0.57 0.58 0.59  0.6 0.62 0.64
##   20    9    7    1 1012    3    6   11   27   52  114   25    2  252  117   32
## 0.65 0.67 0.68 0.69  0.7 0.71 0.72 0.73 0.74 0.75 0.76 0.77 0.78 0.79  0.8 0.81
##    3  754    2   14   55  156    2   35    1  483    6   15   49   13  320    4
## 0.82 0.83 0.84 0.85 0.86 0.87 0.88 0.89  0.9 0.91 0.92 0.93 0.94 0.95 0.96    1
##   23  233    1    9  143    6  108   56   38   17   13    8    4    1    1 2520
```

Hypothesis 1: Attendance correlates with student performance

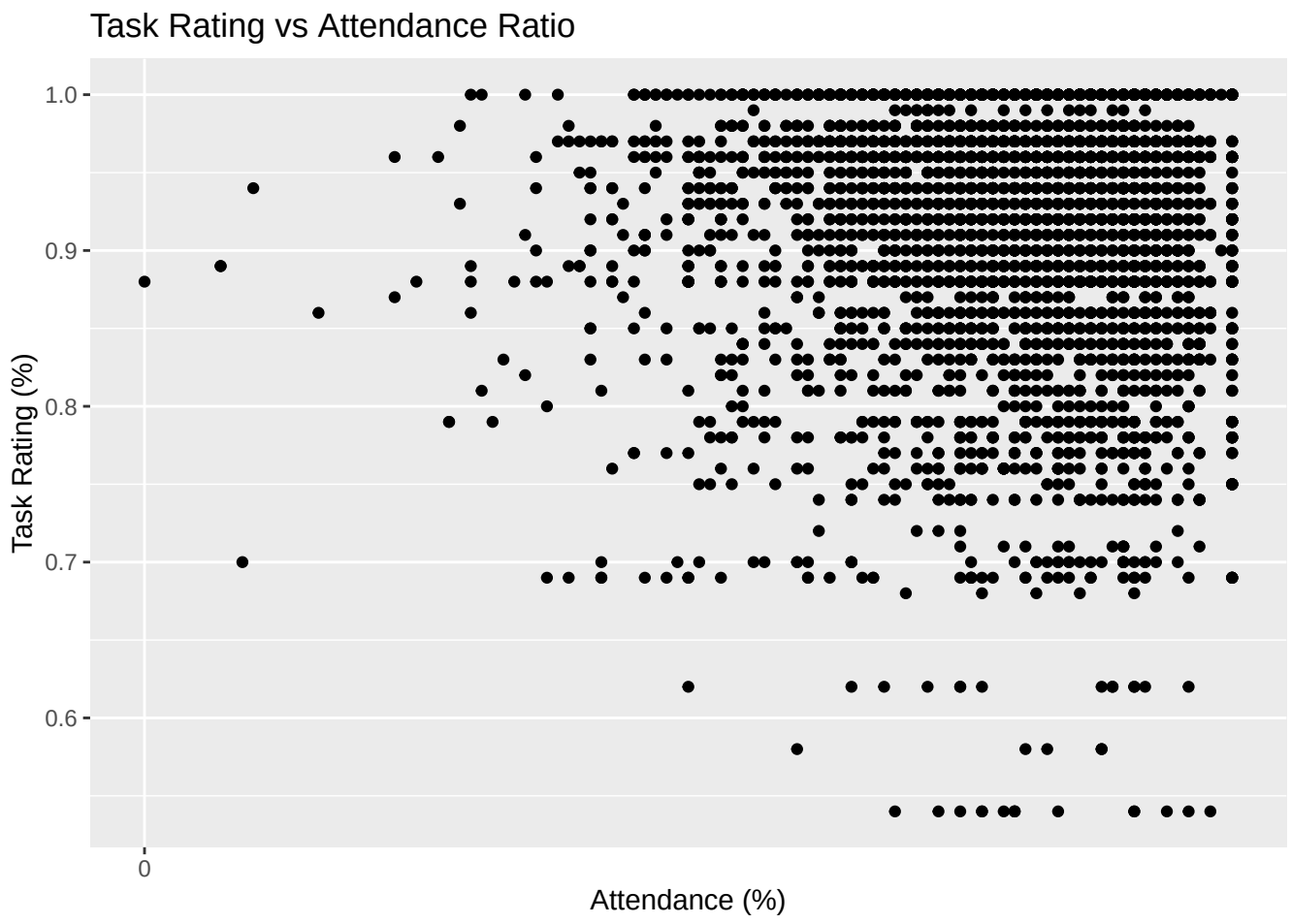
Assumption: Students with higher attendance are more likely to perform better (complete courses) compared to students with low attendance.

Rationale: Students who are actively attending classes may engage more with the material, leading to better performance.

```r
merged_df <- inner_join(student_info, student_performance, by = "TumoID")
```

```r
merged_df$PresenceRatio <- round(as.integer(merged_df$PresenceRatio) / 100, 2)
```

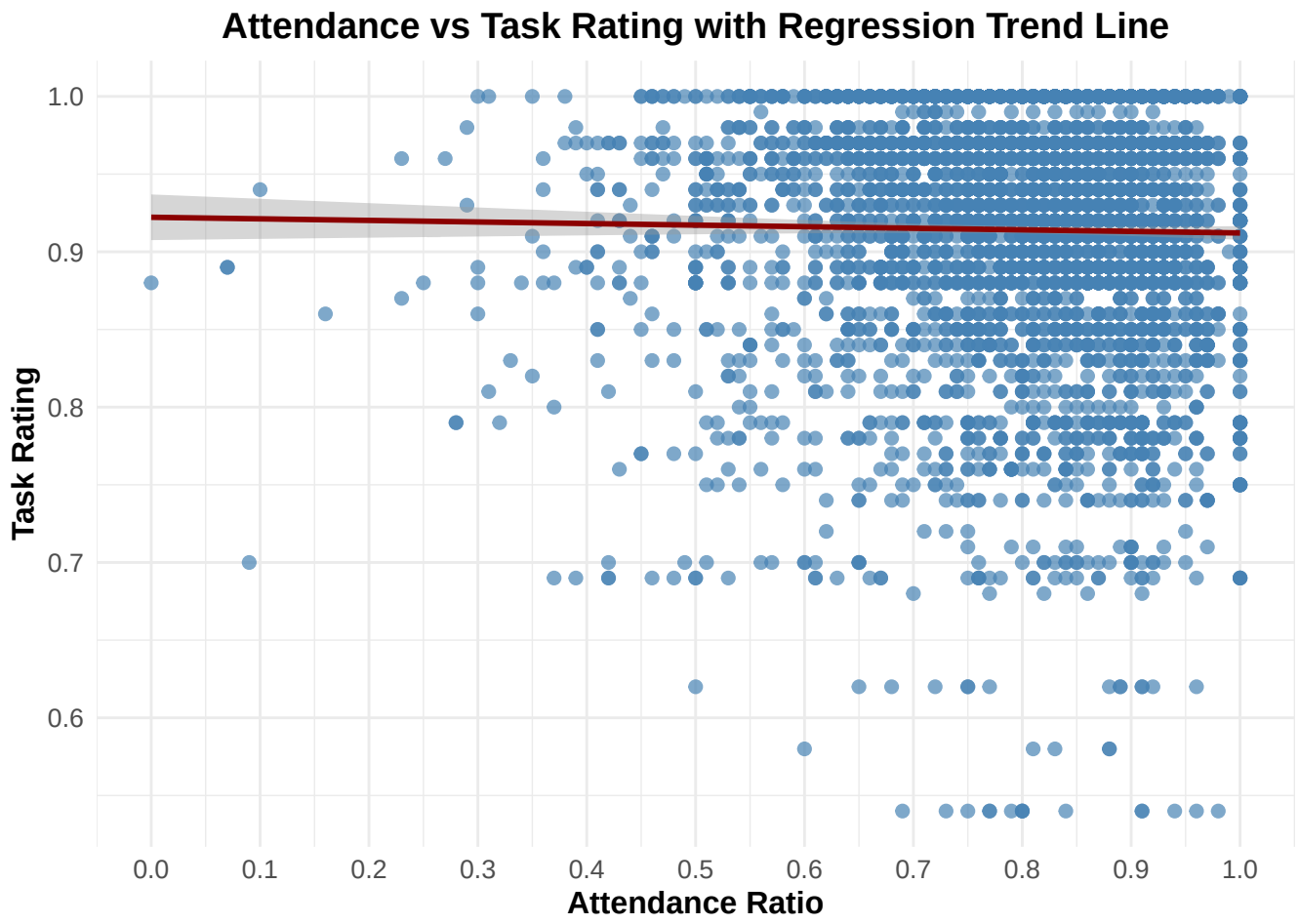
```r
ggplot(merged_df, aes(x = PresenceRatio, y = task_rating)) +
  geom_point() +
  labs(
    title = "Task Rating vs Attendance Ratio",
    x = "Attendance (%)",
    y = "Task Rating (%)"
  ) +
  scale_x_continuous(breaks = seq(0, 100, 10))
```



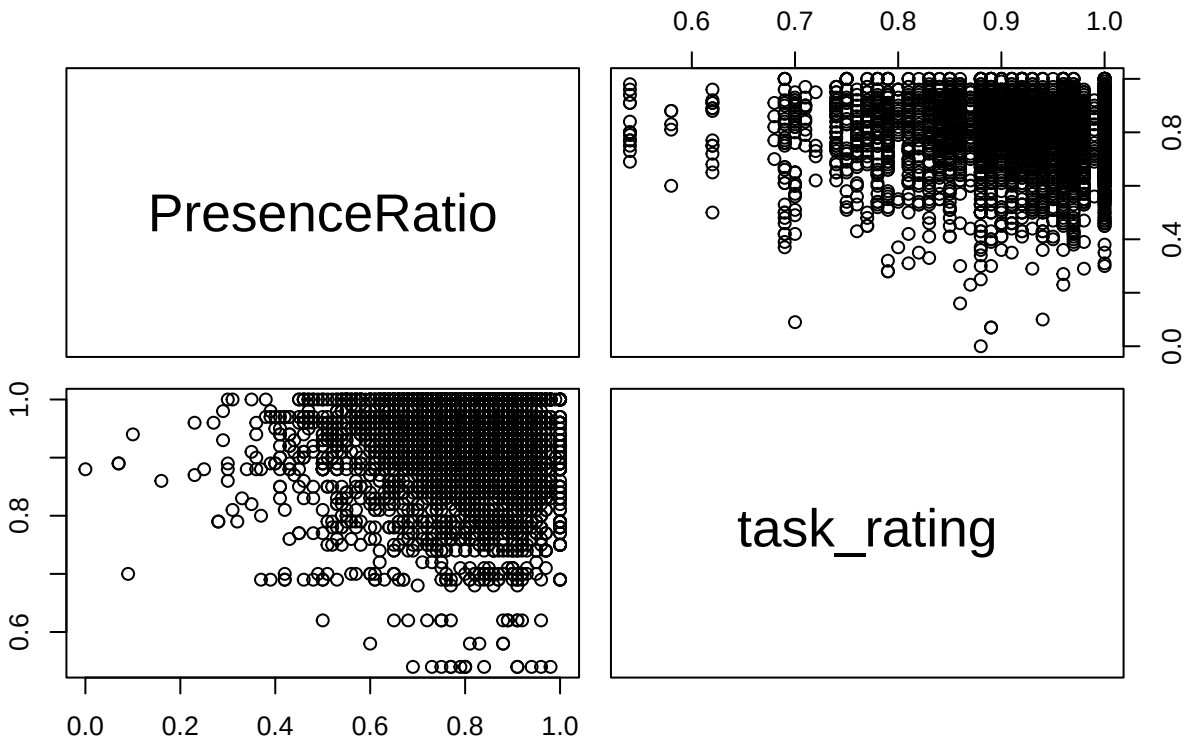
Scatterplot: Presence Rate & Task Rating Trend

```r
ggplot(merged_df, aes(x = PresenceRatio, y = task_rating)) +
  geom_point(color = "steelblue", size = 2, alpha = 0.7) +                    # points
  geom_smooth(method = "lm", se = TRUE, color = "darkred", linewidth = 1) +   # trend line with CI
```

```
  labs(
    title = "Attendance vs Task Rating with Regression Trend Line",
    x = "Attendance Ratio",
    y = "Task Rating"
  ) +
  scale_x_continuous(breaks = seq(0, 1, 0.1)) +                    # ticks every 0.1
  theme_minimal() +
  theme(
    plot.title = element_text(hjust = 0.5, face = "bold", size = 14),
    axis.title = element_text(face = "bold", size = 12),
    axis.text = element_text(size = 10)
  )
```




```
pairs(merged_df[, c("PresenceRatio", "task_rating")],
      main = "Scatterplot Matrix")
```



Linear Relationship: Presence Rate VS Task Rating

```
spearman_cor_test_result <- cor.test(merged_df$PresenceRatio, merged_df$task_rating,
                          method = "spearman", exact = FALSE, use = "complete.obs")
spearman_cor_test_result
```

```
##
##  Spearman's rank correlation rho
##
## data:  merged_df$PresenceRatio and merged_df$task_rating
## S = 13193615048, p-value = 0.0003643
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##         rho
## -0.05486129
```

Monotonicity: Presence Rate VS Task Rating

```r
pearson_cor_test_result <- cor.test(merged_df$PresenceRatio, merged_df$task_rating,
                            method = "pearson", exact = FALSE, use = "complete.obs")
pearson_cor_test_result
```

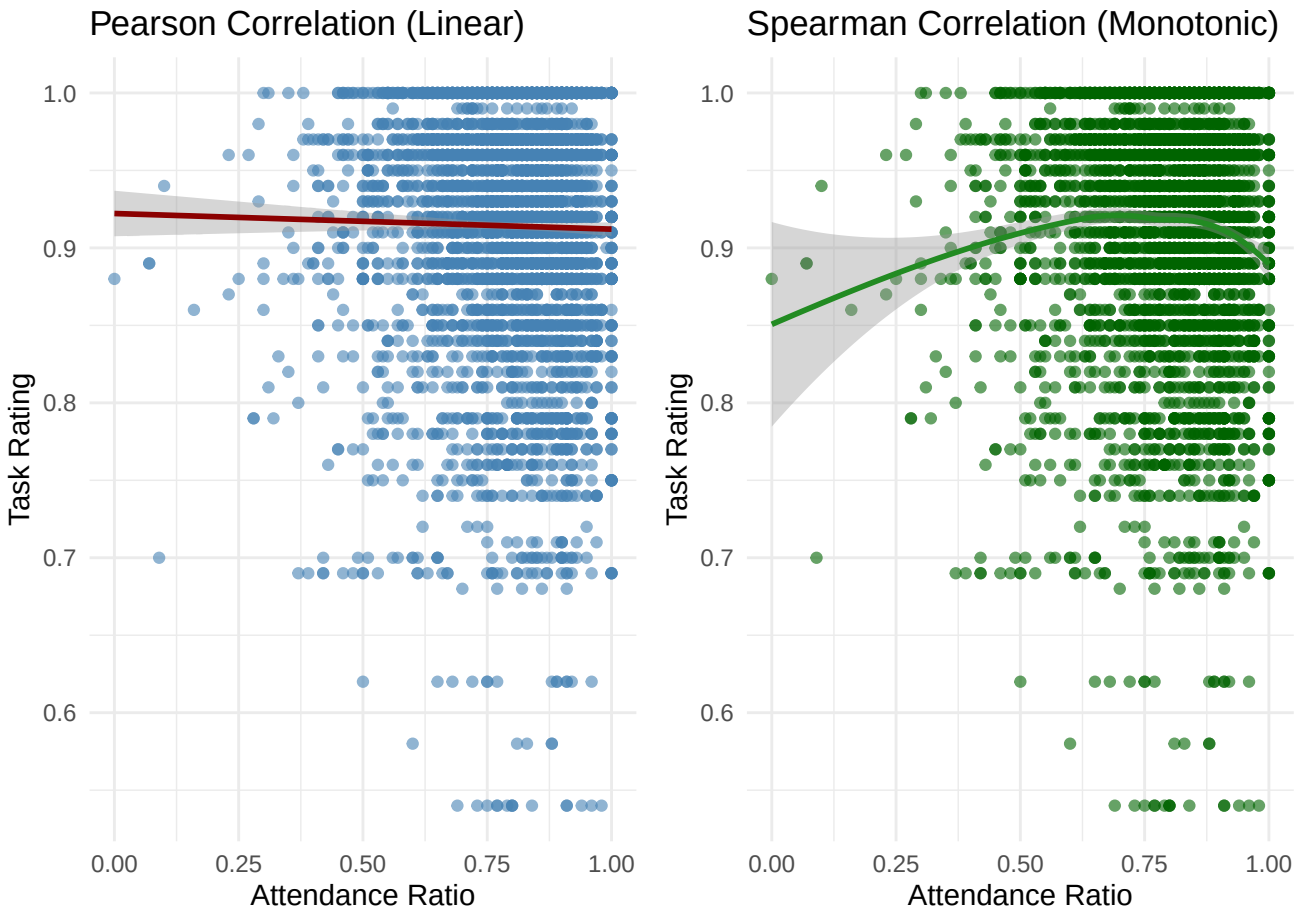
```
##
##  Pearson's product-moment correlation
##
## data:  merged_df$PresenceRatio and merged_df$task_rating
## t = -1.0881, df = 4216, p-value = 0.2766
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.04691147  0.01343134
## sample estimates:
##         cor
## -0.01675532
```

Linearity and Monotonicity Plots

```r
p1 <- ggplot(merged_df, aes(x = PresenceRatio, y = task_rating)) +
  geom_point(alpha = 0.6, color = "steelblue") +
  geom_smooth(method = "lm", se = TRUE, color = "darkred") +
  labs(title = "Pearson Correlation (Linear)",
       x = "Attendance Ratio",
       y = "Task Rating") +
  theme_minimal()

# Spearman scatterplot with loess smooth (captures monotonic relationship)
p2 <- ggplot(merged_df, aes(x = PresenceRatio, y = task_rating)) +
  geom_point(alpha = 0.6, color = "darkgreen") +
  geom_smooth(method = "loess", se = TRUE, color = "forestgreen") +
  labs(title = "Spearman Correlation (Monotonic)",
       x = "Attendance Ratio",
       y = "Task Rating") +
  theme_minimal()

p1 + p2
```



Hypothesis 2: Number of courses started impacts performance outcomes

Assumption: Students who start more courses may either demonstrate strong engagement or be overwhelmed, which could lead to different performance outcomes (completed, failed, or withdrawn).

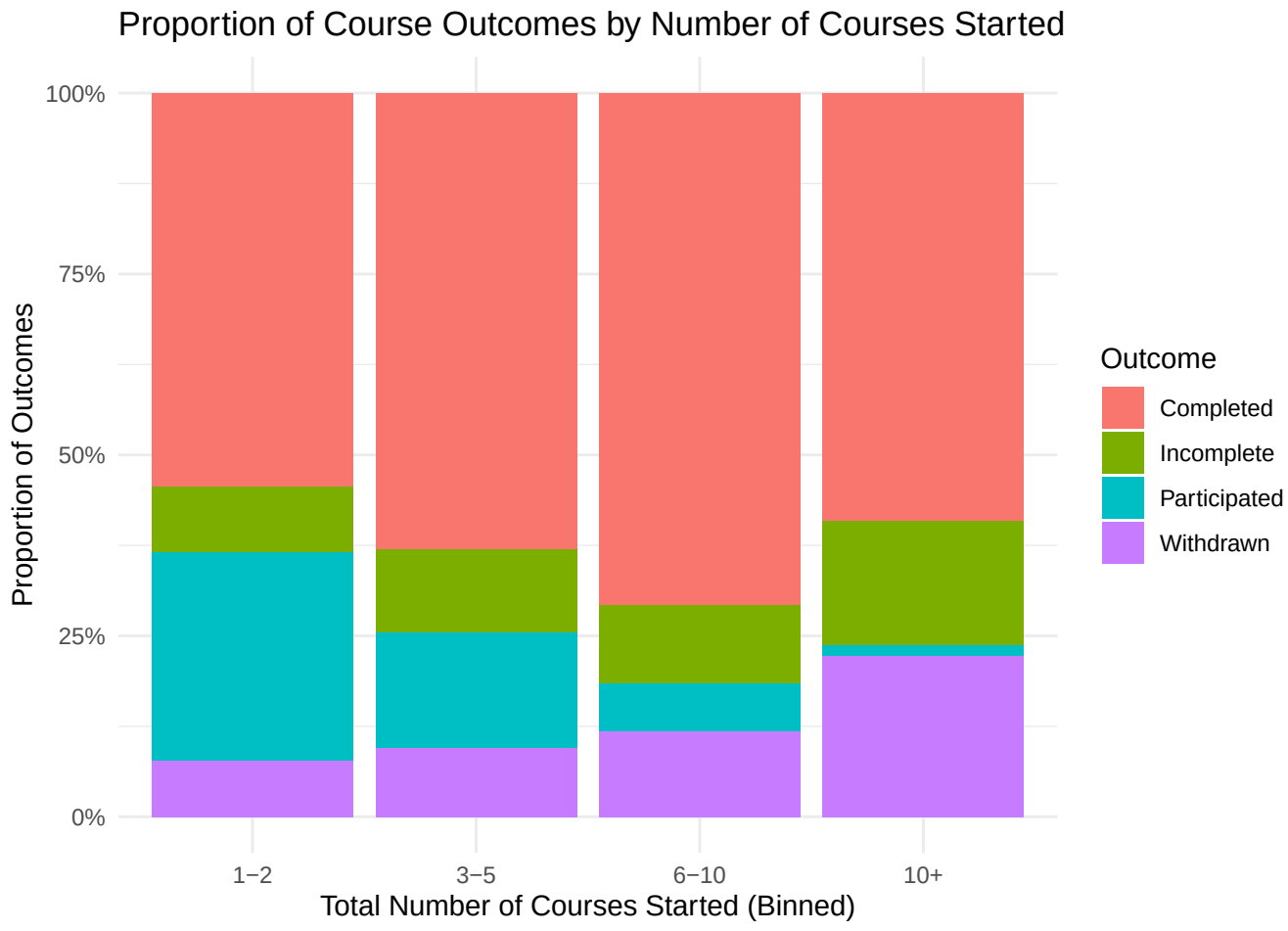
Rationale: Engaging with multiple courses may indicate either strong motivation or poor focus/time management skills, both of which could affect performance outcomes.

```
course_outcomes <- merged_df %>%
  mutate(total_courses = Completed + Incomplete + Participated + Withdrawn) %>%
  pivot_longer(
    cols = c(Completed, Incomplete, Participated, Withdrawn),
    names_to = "Outcome",
    values_to = "Count"
  )
```

Proportion of Course Outcomes by Number of Courses Started

```
course_outcomes <- course_outcomes %>%
  mutate(total_bin = cut(total_courses, breaks = c(0, 2, 5, 10, Inf),
                         labels = c("1-2", "3-5", "6-10", "10+"), right = FALSE))

ggplot(course_outcomes, aes(x = total_bin, y = Count, fill = Outcome)) +
  geom_bar(stat = "identity", position = "fill") +
  scale_y_continuous(labels = percent_format()) +
  labs(
    title = "Proportion of Course Outcomes by Number of Courses Started",
    x = "Total Number of Courses Started (Binned)",
    y = "Proportion of Outcomes",
    fill = "Outcome"
  ) +
  theme_minimal()
```




```
df <- merged_df %>%
  mutate(
    total_courses = Completed + Participated + Rejected + Withdrawn,
```

```
    course_volume_group = cut(
      total_courses,
      breaks = c(-Inf, 2, 5, 10, Inf),
      labels = c("1-2", "3-5", "6-10", "10+")
    )
  )

outcome_table <- df %>%
  group_by(course_volume_group) %>%
  summarise(
    Completed = sum(Completed, na.rm = TRUE),
    Participated = sum(Participated, na.rm = TRUE),
    Failed = sum(Rejected, na.rm = TRUE),
    Withdrawn = sum(Withdrawn, na.rm = TRUE)
  )
```

```
outcome_matrix <- as.matrix(outcome_table[, -1])
rownames(outcome_matrix) <- outcome_table$course_volume_group
chisq_result <- chisq.test(outcome_matrix)
```

```
outcome_matrix
```

```
##      Completed Participated Failed Withdrawn
## 1-2        428          128    644        56
## 3-5       2355          557   2685       406
## 6-10      4782          746   5227       865
## 10+       2266           38   1568       631
```

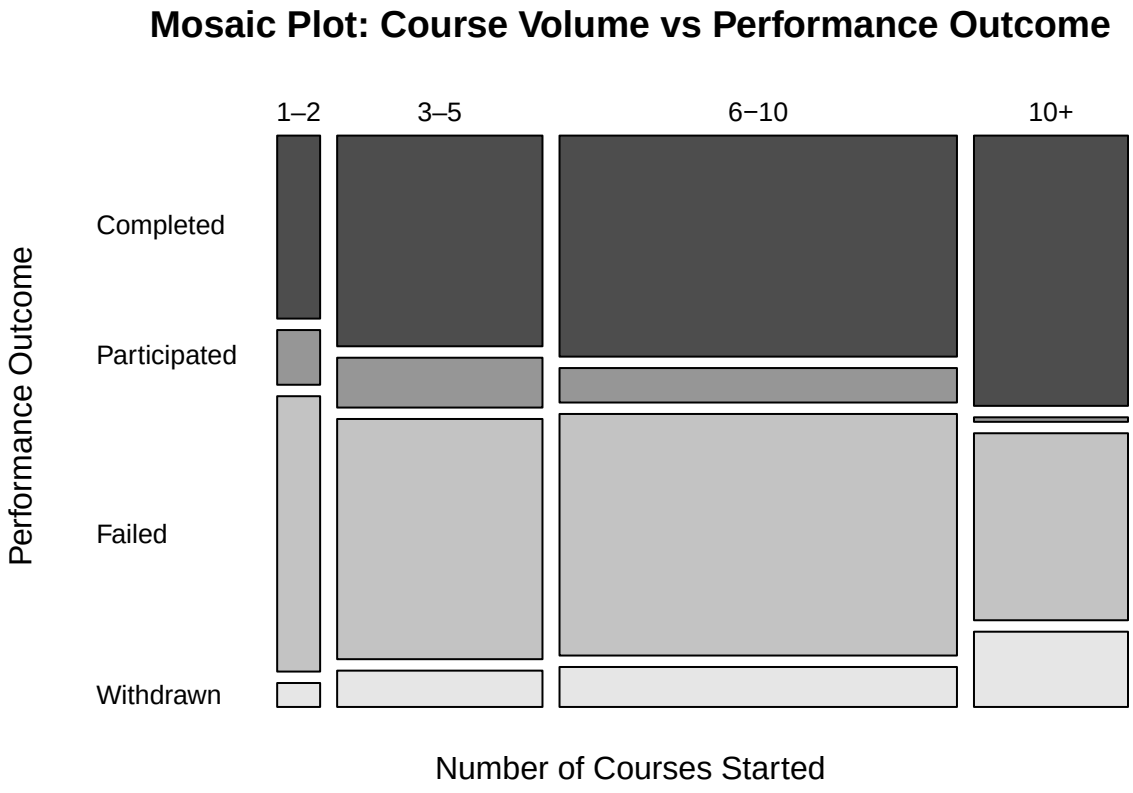
Variable Independence Test

```
chisq_result
```

```
##
##  Pearson's Chi-squared test
##
## data:  outcome_matrix
## X-squared = 762.73, df = 9, p-value < 0.00000000000000022
```

Course Volume VS Performance Outcome

```
mosaicplot(outcome_matrix,
           main = "Mosaic Plot: Course Volume vs Performance Outcome",
           color = TRUE,
           xlab = "Number of Courses Started",
           ylab = "Performance Outcome",
           las = 1,
           cex.axis = 0.8)
```



Hypothesis 3: Withdrawn students show different behavioral patterns than those who fail or complete courses.

Assumption: They have distinct engagement traits (e.g., lower attendance or fewer tasks completed).

Rationale: Withdrawals may stem from personal or motivational issues, reflected in measurable behavior.

```
merged_df$main_outcome_group <- case_when(
  merged_df$Withdrawn > 0 ~ "Withdrawn",
  merged_df$Completed > 0 ~ "Completed",
  merged_df$Rejected > 0 ~ "Failed",
  TRUE ~ "Other"
)
```

T-Test: Withdrawn vs Completed

```
t.test(PresenceRatio ~ main_outcome_group,
       data = merged_df %>% filter(main_outcome_group %in% c("Withdrawn", "Completed")))
```

```
##
##  Welch Two Sample t-test
##
## data:  PresenceRatio by main_outcome_group
## t = 6.3982, df = 2091.9, p-value = 0.0000000001934
## alternative hypothesis: true difference in means between group Completed and group Withdrawn is not
## 95 percent confidence interval:
##  0.02077441 0.03913800
## sample estimates:
## mean in group Completed mean in group Withdrawn
##               0.8026398               0.7726836
```

T-Test: Withdrawn vs Failed

```
t.test(PresenceRatio ~ main_outcome_group,
       data = merged_df %>% filter(main_outcome_group %in% c("Withdrawn", "Failed")))
```

```
##
##  Welch Two Sample t-test
##
## data:  PresenceRatio by main_outcome_group
## t = 5.8457, df = 1558.9, p-value = 0.000000006131
## alternative hypothesis: true difference in means between group Failed and group Withdrawn is not equa
## 95 percent confidence interval:
##  0.02520169 0.05065455
## sample estimates:
##    mean in group Failed mean in group Withdrawn
##               0.8106117               0.7726836
```

Principal Component Analysis (PCA)

Understanding PCA

Principal Component Analysis (PCA) reduces high-dimensional data into fewer dimensions by transforming correlated variables into uncorrelated components, where each component captures the **maximum possible variance** in the data.

```
df_numeric <- merged_df %>%
  select(where(is.numeric)) %>%
  na.omit()

groups <- merged_df %>%
  filter(complete.cases(select(., where(is.numeric)))) %>%
  pull(main_outcome_group)
```

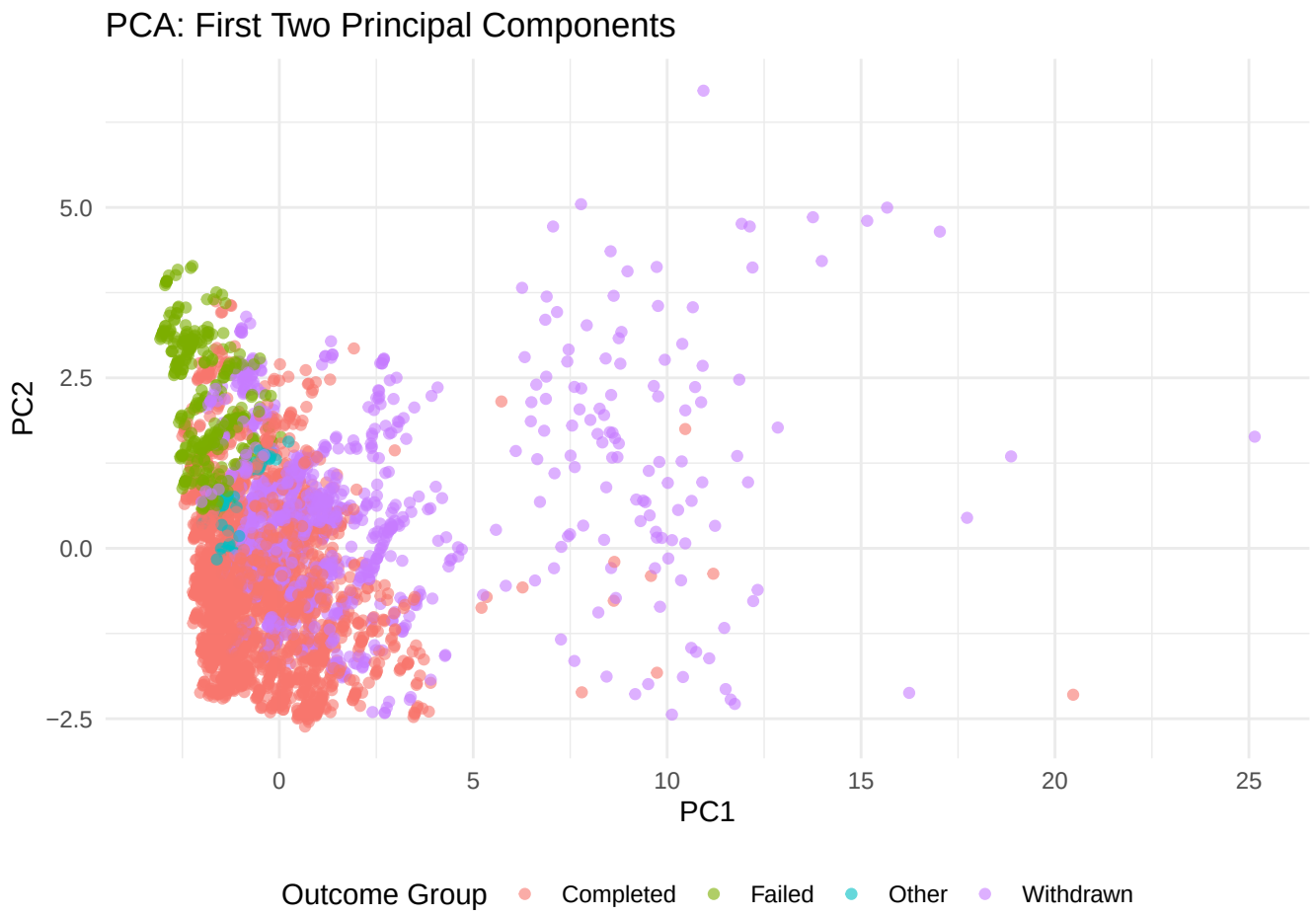
```
pca_result <- prcomp(df_numeric, center = TRUE, scale. = TRUE)

pca_df <- as.data.frame(pca_result$x)
pca_df$Group <- groups
```

We use prcomp() with centering and scaling to ensure equal weighting across features.

PCA Plot: First Two Principal Components

```
ggplot(pca_df, aes(x = PC1, y = PC2, color = Group)) +
  geom_point(alpha = 0.6, size = 1.5) +
  labs(title = "PCA: First Two Principal Components",
       color = "Outcome Group") +
  theme_minimal() +
  theme(legend.position = "bottom")
```



If Withdrawn points cluster separately from Completed or Failed, this supports the hypothesis: withdrawn students behave differently.