# Final Project

### Introduction

### The Data

We will be using data that has extensive information on secondary school students in their math class.

```
data <- read.csv("data/student-mat.csv")
```

### Creation of New Variables

In order to provide more insight, we saw room to create informative variables based upon the given data.

The given variables Medu and Fedu give information about the student's parents education history. Using this, we created a new variable "first_gen_college" that indicates if the student would be a first generation college student if they decided to pursue higher education. This will give more tangible and clear insight to how parental education impacts student's performance.

```
data <- data %>%
  mutate(first_gen_college = case_when(
    Medu < 4 & Fedu < 4 ~ "yes",
    TRUE ~"no"
  ))
```

Additionally, many variables are self reported ratings from the students on a scale of 1-5. We decided that instead factoring these variables so that scores of 1-3 would be "low" and scores of 4-5 would be "high" would be beneficial to our analysis as it would be more interpretable in context.

```
data <- data %>%
  mutate(famrel = case_when(
    famrel == 1 ~ "low",
    famrel == 2 ~ "low",
    famrel == 3 ~ "low",
    famrel == 4 ~ "high",
    famrel == 5 ~"high"
  ))

data <- data %>%
  mutate(freetime = case_when(
    freetime == 1 ~ "low",
    freetime == 2 ~ "low",
    freetime == 3 ~ "low",
    freetime == 4 ~ "high",
    freetime == 5 ~"high"
  ))

data <- data %>%
  mutate(goout = case_when(
    goout == 1 ~ "low",
    goout == 2 ~ "low",
    goout == 3 ~ "low",
```

```
    goout == 4 ~ "high",
    goout == 5 ~"high"
  ))

data <- data %>%
  mutate(Dalc = case_when(
    Dalc == 1 ~ "low",
    Dalc == 2 ~ "low",
    Dalc == 3 ~ "low",
    Dalc == 4 ~ "high",
    Dalc == 5 ~"high"
  ))

data <- data %>%
  mutate(Walc = case_when(
    Walc == 1 ~ "low",
    Walc == 2 ~ "low",
    Walc == 3 ~ "low",
    Walc == 4 ~ "high",
    Walc == 5 ~"high"
  ))

data <- data %>%
  mutate(health = case_when(
    health == 1 ~ "low",
    health == 2 ~ "low",
    health == 3 ~ "low",
    health == 4 ~ "high",
    health == 5 ~"high"
  ))
```

Additionally, using information from the famsup and internet variables, we created a variable called "stable_learning_env". If famsup is "yes" and internet is "yes", then stable_learning_env is "yes", otherwise "no".

```
data <- data %>%
  mutate(stable_learning_env = case_when(
    internet =="yes" & famsup =="yes" ~"yes",
    TRUE ~"no"
  ))
```

Also, we created a new variable "high_freq_absent", which if absences >= 10 for a student, we considered them a highly frequent student.

```
data <- data %>%
  mutate(high_freq_absent = case_when(
    absences >= 10 ~"yes",
    TRUE ~"no"
  ))
```

We also created a "failed" variable, which was "yes" if failures > 0, and "no" otherwise.

```
data <- data %>%
  mutate(failed = case_when(
    failures > 0 ~"yes",
    TRUE ~"no"
```

```
  ))
```

### Exploratory Data Analysis

```
summary(data)
```

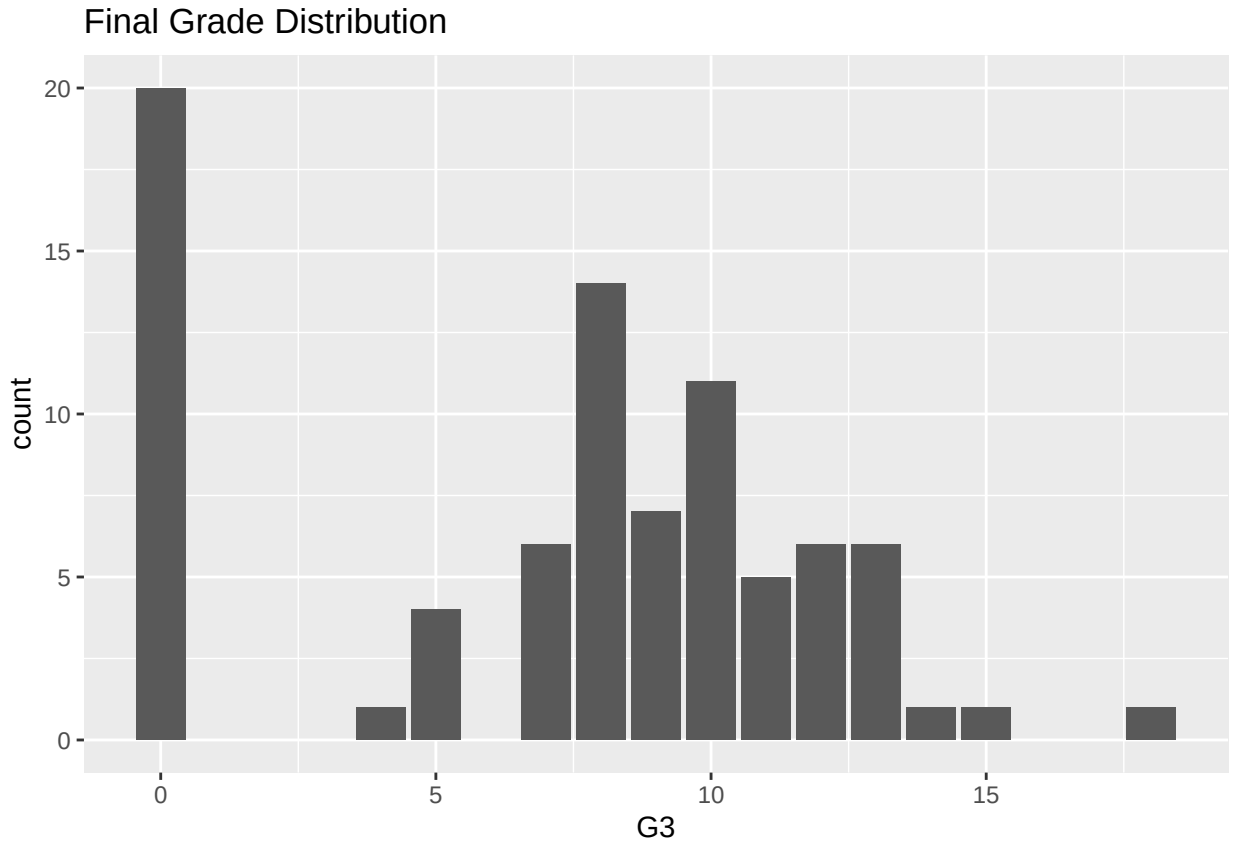
```
##     school              sex                 age         address
##  Length:395         Length:395         Min.   :15.0   Length:395
##  Class :character   Class :character   1st Qu.:16.0   Class :character
##  Mode  :character   Mode  :character   Median :17.0   Mode  :character
##                                        Mean   :16.7
##                                        3rd Qu.:18.0
##                                        Max.   :22.0
##    famsize            Pstatus              Medu            Fedu
##  Length:395         Length:395         Min.   :0.000   Min.   :0.000
##  Class :character   Class :character   1st Qu.:2.000   1st Qu.:2.000
##  Mode  :character   Mode  :character   Median :3.000   Median :2.000
##                                        Mean   :2.749   Mean   :2.522
##                                        3rd Qu.:4.000   3rd Qu.:3.000
##                                        Max.   :4.000   Max.   :4.000
##      Mjob               Fjob               reason            guardian
##  Length:395         Length:395         Length:395         Length:395
##  Class :character   Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character
##
##
##
##    traveltime      studytime        failures       schoolsup
##  Min.   :1.000   Min.   :1.000   Min.   :0.0000   Length:395
##  1st Qu.:1.000   1st Qu.:1.000   1st Qu.:0.0000   Class :character
##  Median :1.000   Median :2.000   Median :0.0000   Mode  :character
##  Mean   :1.448   Mean   :2.035   Mean   :0.3342
##  3rd Qu.:2.000   3rd Qu.:2.000   3rd Qu.:0.0000
##  Max.   :4.000   Max.   :4.000   Max.   :3.0000
##     famsup              paid            activities          nursery
##  Length:395         Length:395         Length:395         Length:395
##  Class :character   Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character
##
##
##
##     higher            internet           romantic            famrel
##  Length:395         Length:395         Length:395         Length:395
##  Class :character   Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character
##
##
##
##    freetime            goout              Dalc              Walc
##  Length:395         Length:395         Length:395         Length:395
##  Class :character   Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character
##
```

```
##
##
##     health            absences            G1              G2
##  Length:395         Min.   : 0.000   Min.   : 3.00   Min.   : 0.00
##  Class :character   1st Qu.: 0.000   1st Qu.: 8.00   1st Qu.: 9.00
##  Mode  :character   Median : 4.000   Median :11.00   Median :11.00
##                     Mean   : 5.709   Mean   :10.91   Mean   :10.71
##                     3rd Qu.: 8.000   3rd Qu.:13.00   3rd Qu.:13.00
##                     Max.   :75.000   Max.   :19.00   Max.   :19.00
##        G3        first_gen_college  stable_learning_env high_freq_absent
##  Min.   : 0.00   Length:395         Length:395          Length:395
##  1st Qu.: 8.00   Class :character   Class :character    Class :character
##  Median :11.00   Mode  :character   Mode  :character    Mode  :character
##  Mean   :10.42
##  3rd Qu.:14.00
##  Max.   :20.00
##     failed
##  Length:395
##  Class :character
##  Mode  :character
##
##
##
```

First, I will start off with univariate and bivariate plots of the response variable and key predictors I see being important.

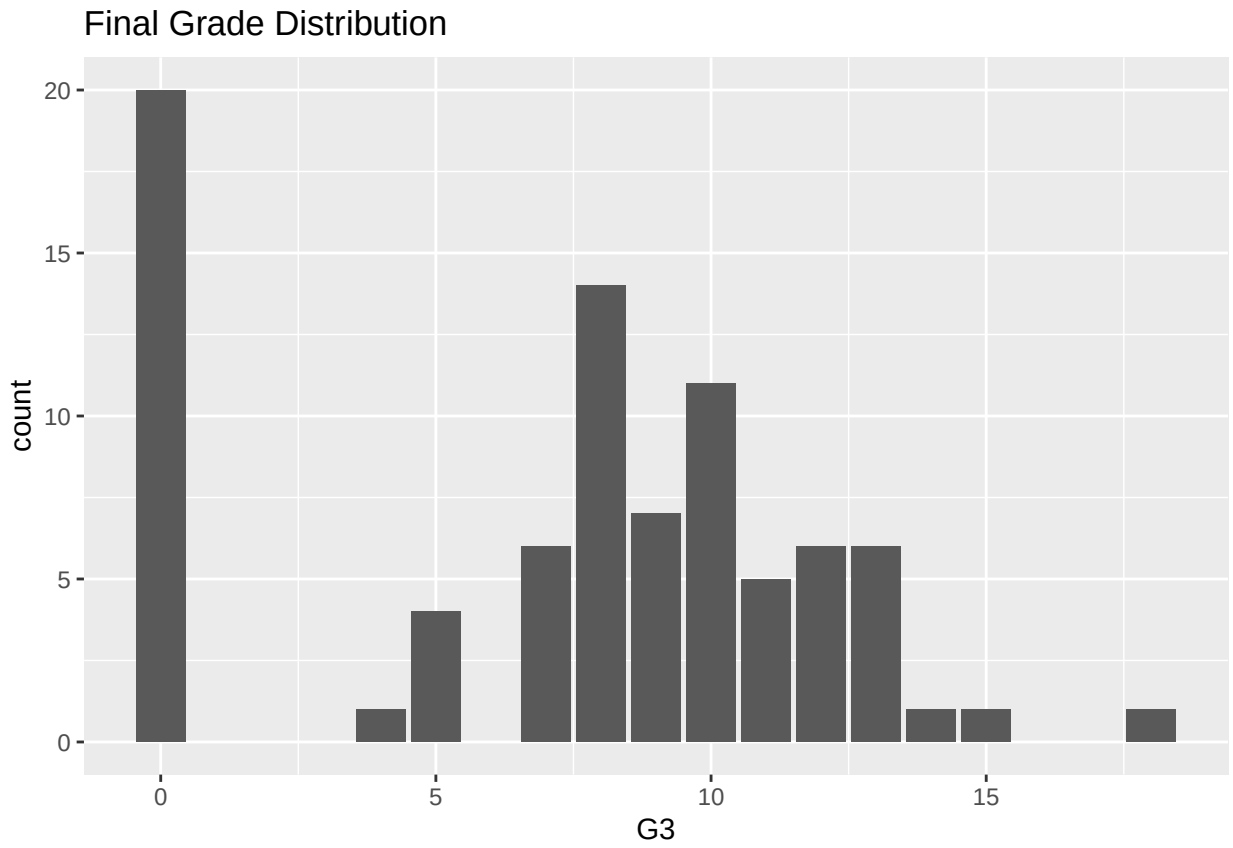
```
data %>%
  filter(failed =="yes") %>%
  ggplot(aes(G3)) +
  geom_histogram(stat = "count") +
  labs(title="Final Grade Distribution")
```

```
## Warning: Ignoring unknown parameters: binwidth, bins, pad
```



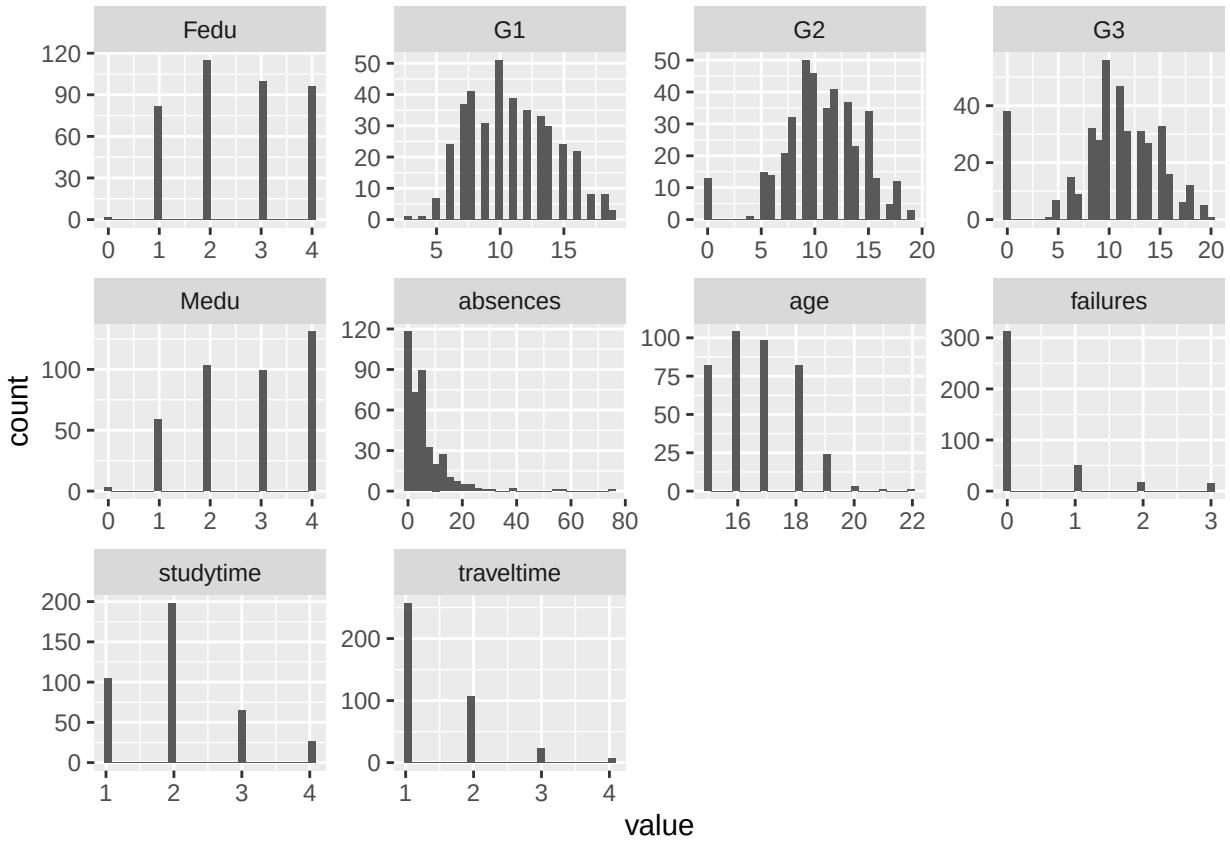

```
data %>%
  filter(failed =="yes") %>%
  ggplot(aes(G3)) +
  geom_histogram(stat = "count") +
  labs(title="Final Grade Distribution")
```

```
## Warning: Ignoring unknown parameters: binwidth, bins, pad
```



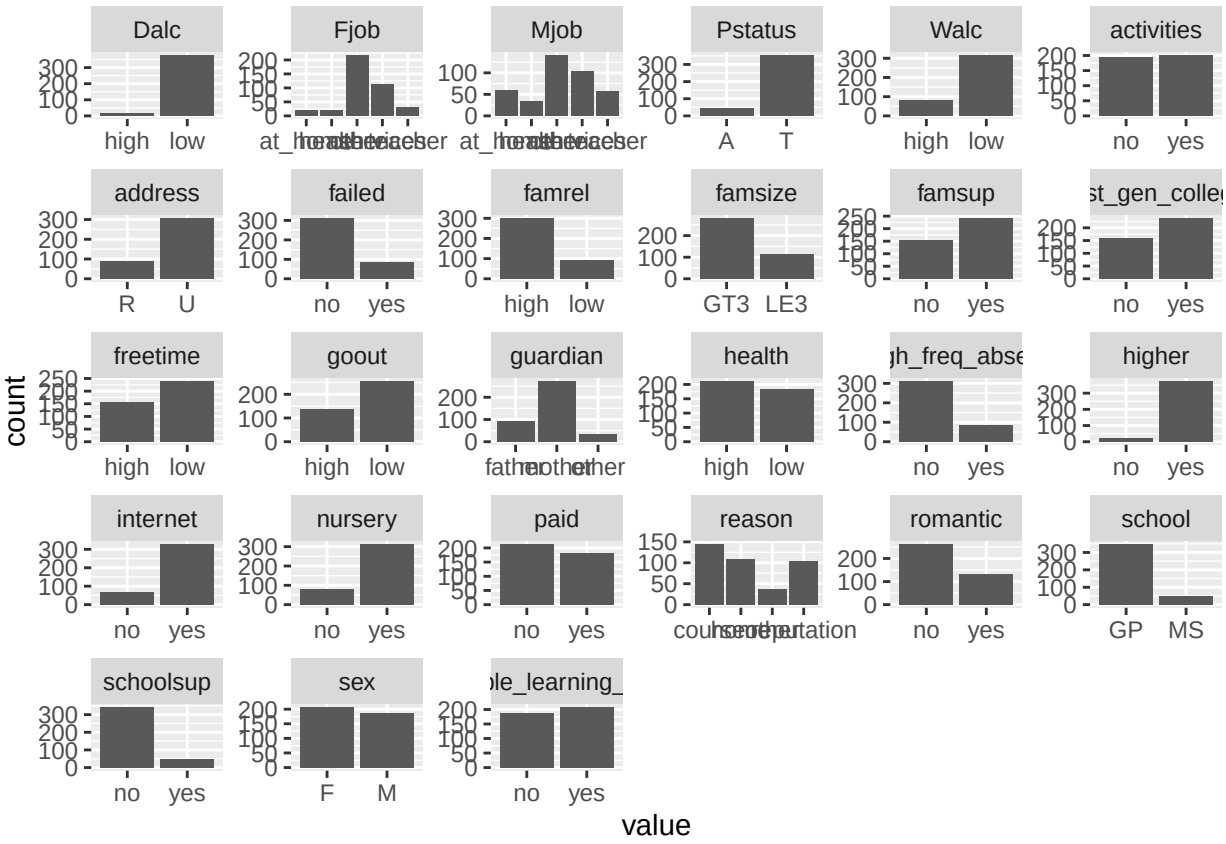

```
data %>%
  keep(is.numeric) %>%
  gather() %>%
  ggplot(aes(value)) +
    facet_wrap(~ key, scales = "free") +
    geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



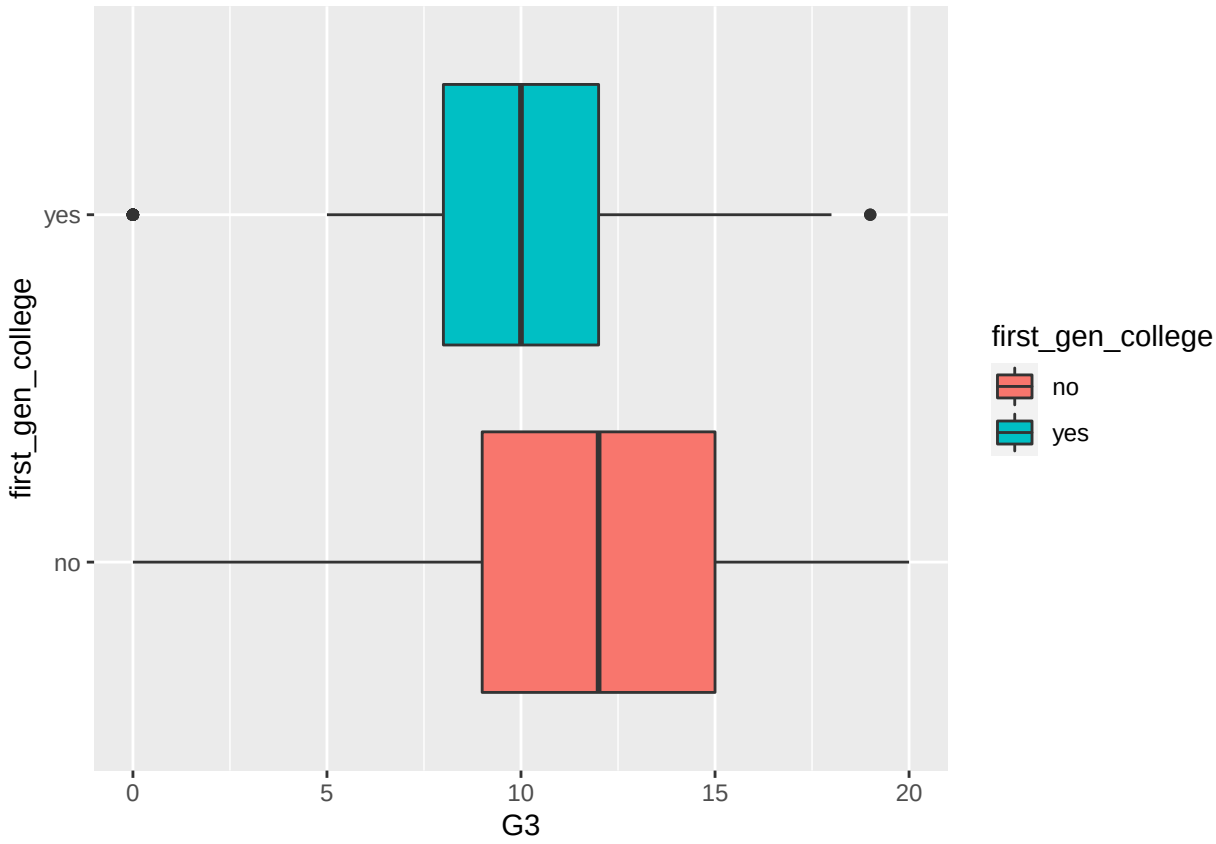

```
data %>%
  keep(is.character) %>%
  gather() %>%
  ggplot(aes(value)) +
    facet_wrap(~ key, scales = "free") +
    geom_histogram(stat="count")
```

```
## Warning: Ignoring unknown parameters: binwidth, bins, pad
```

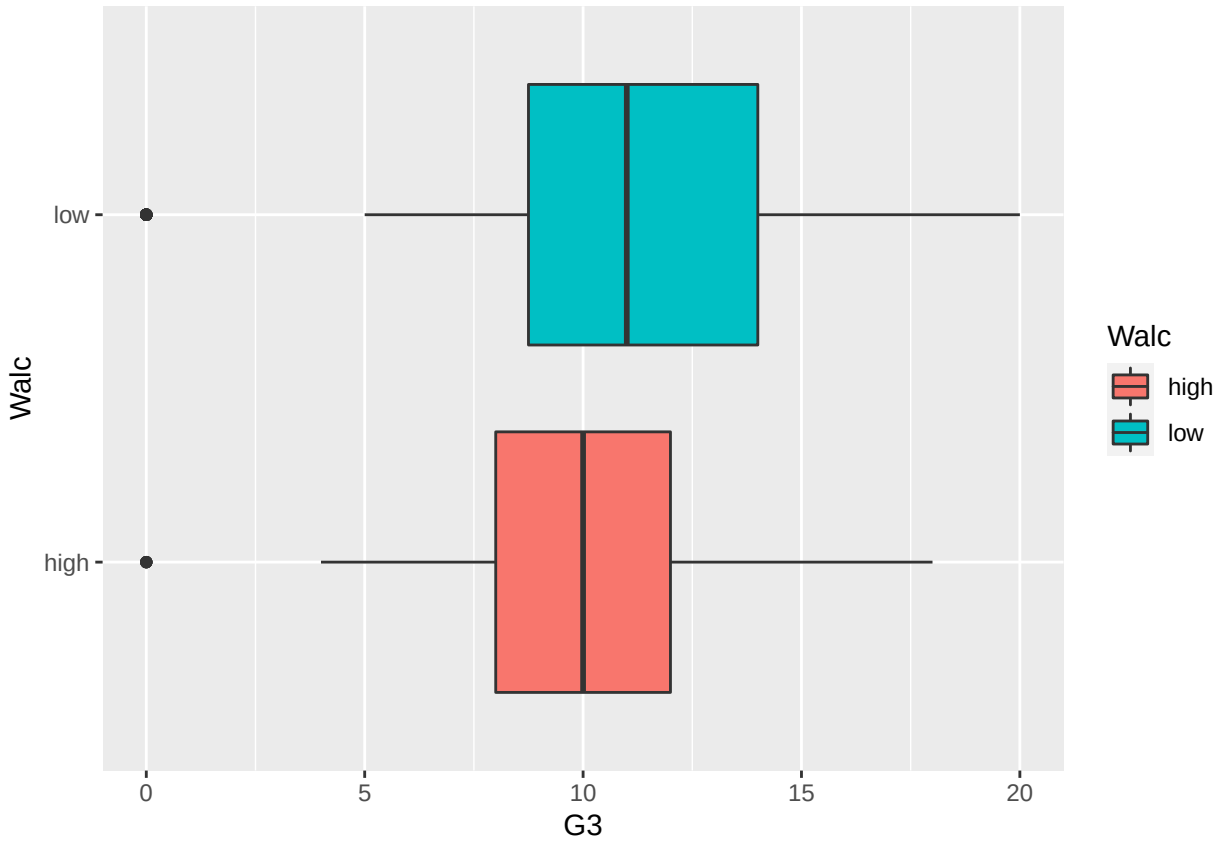



Above we see that the response variable, G3, is pretty normally distributed, thus no transformation is necessary,

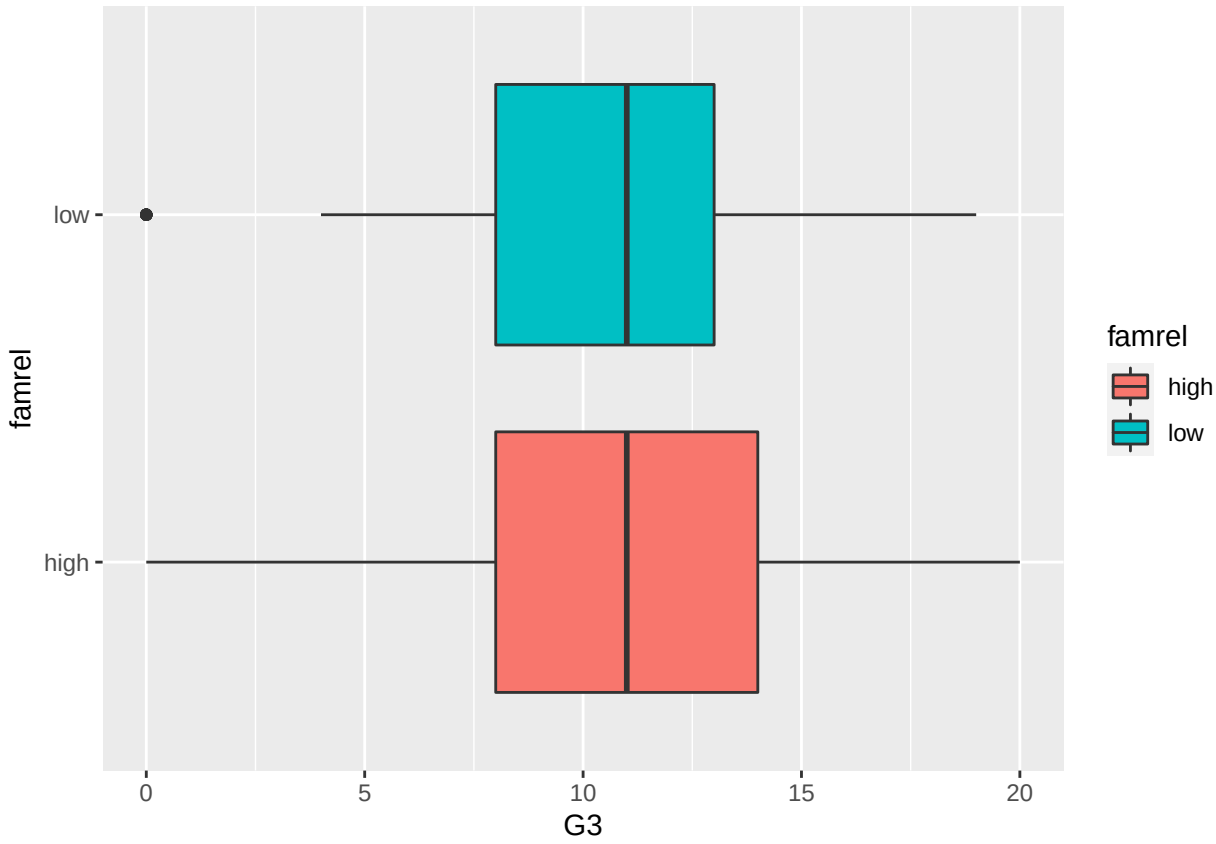
```
ggplot(data = data, aes(x = G3, y = first_gen_college, fill=first_gen_college)) +
  geom_boxplot()
```



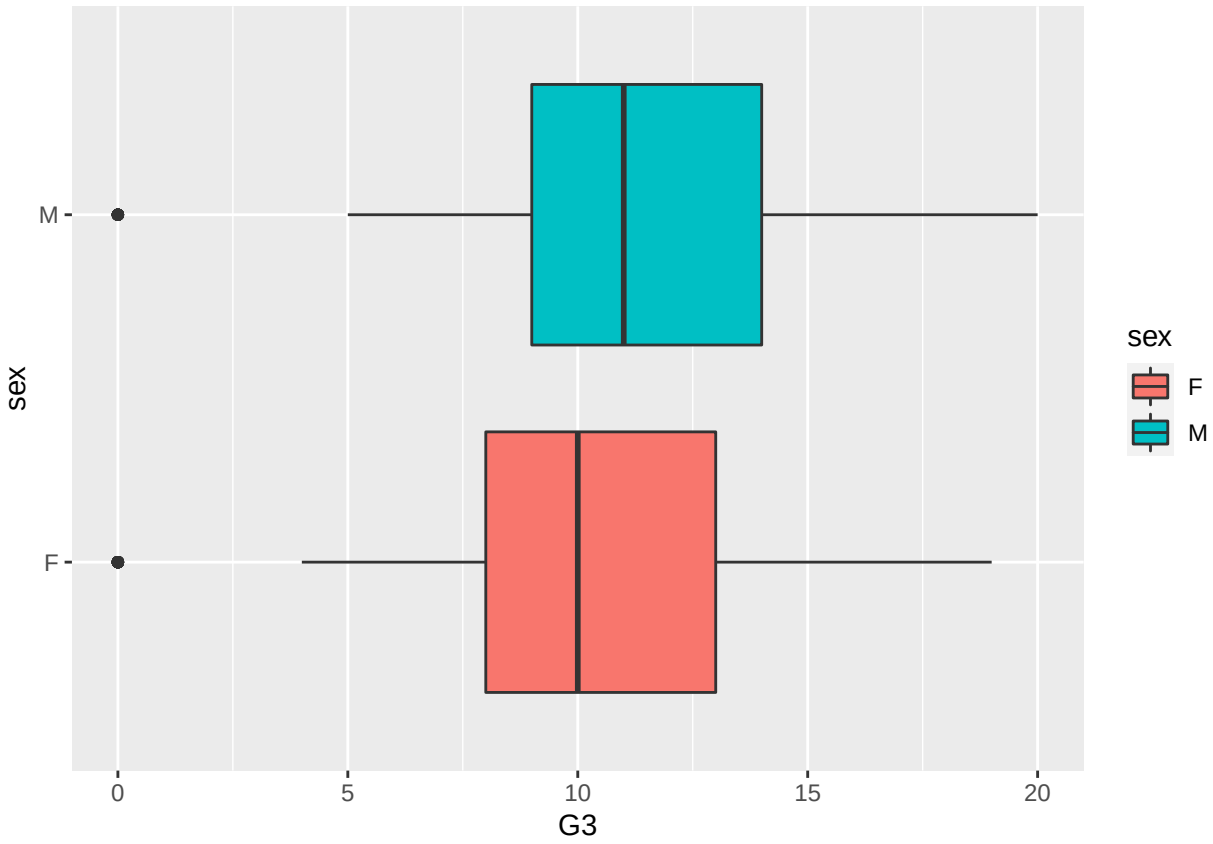

```
ggplot(data = data, aes(x = G3, y = Walc, fill = Walc)) +
  geom_boxplot()
```



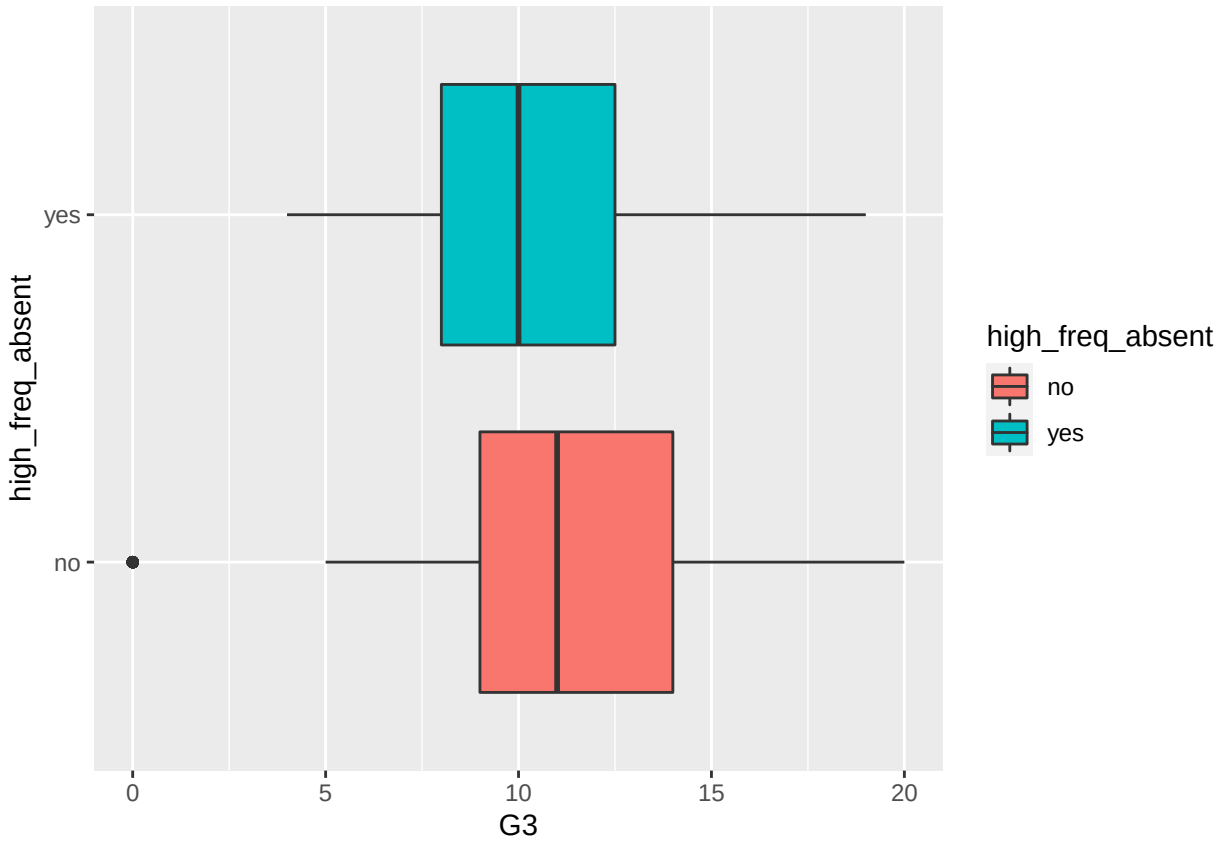

```
ggplot(data = data, aes(x = G3, y = famrel, fill = famrel)) +
  geom_boxplot()
```



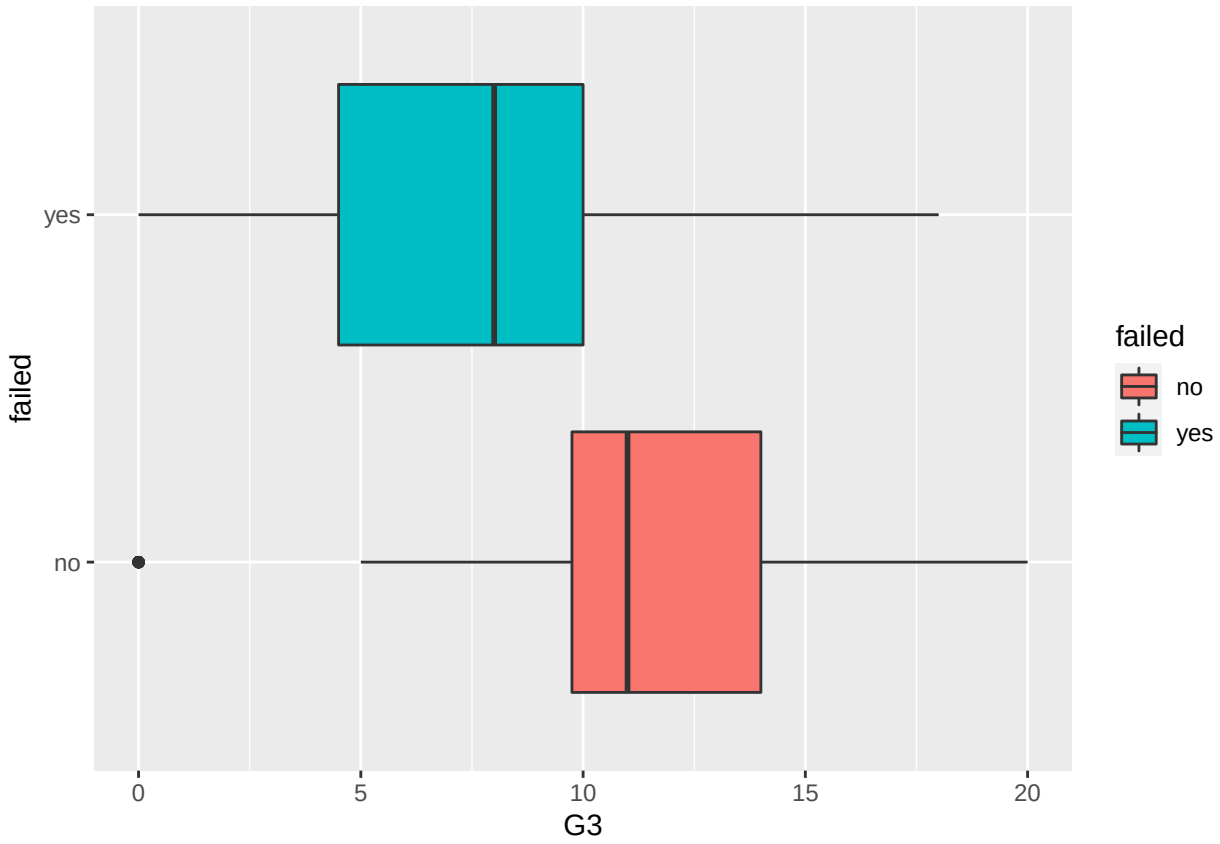

```
ggplot(data = data, aes(x = G3, y= sex, fill = sex)) +
  geom_boxplot()
```



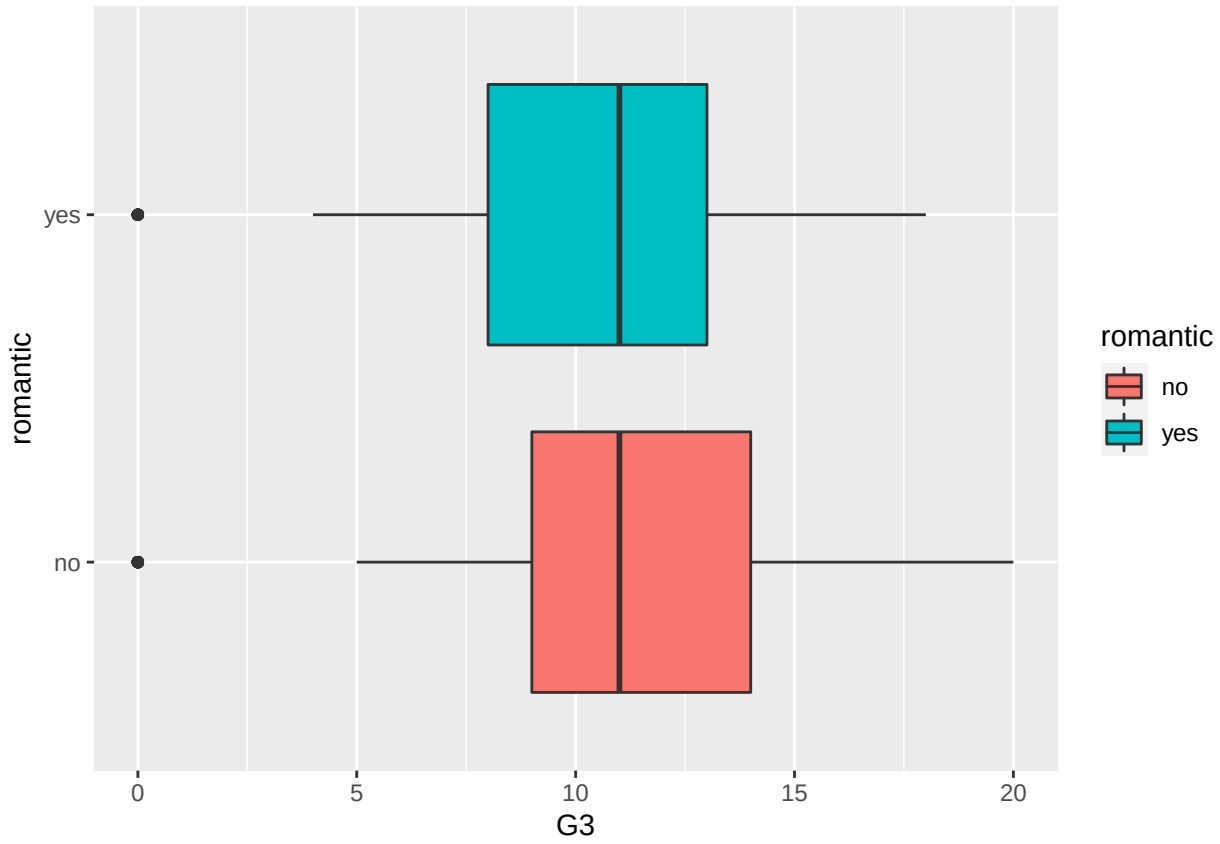

```
ggplot(data = data, aes(x = G3, y = high_freq_absent, fill = high_freq_absent)) +
  geom_boxplot()
```



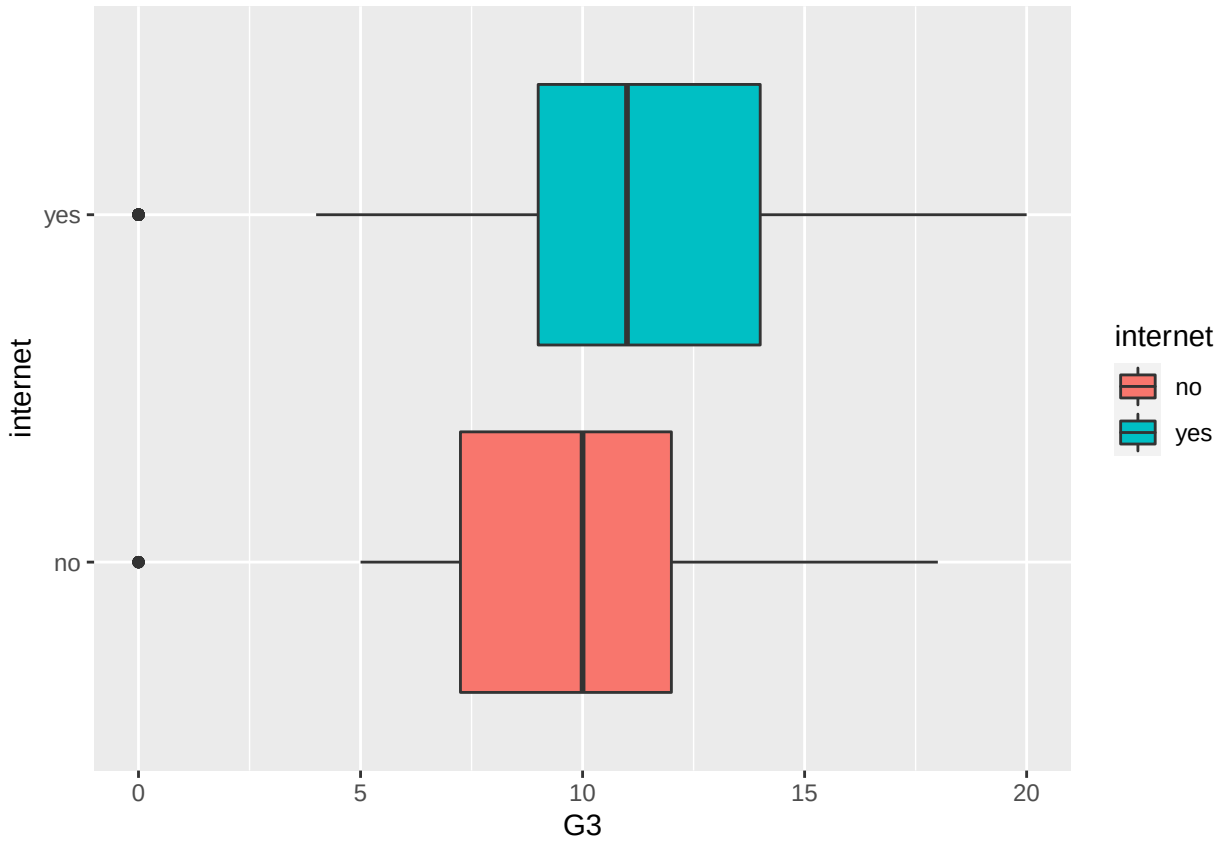

```
ggplot(data = data, aes(x = G3, y=failed, fill = failed)) +
  geom_boxplot()
```



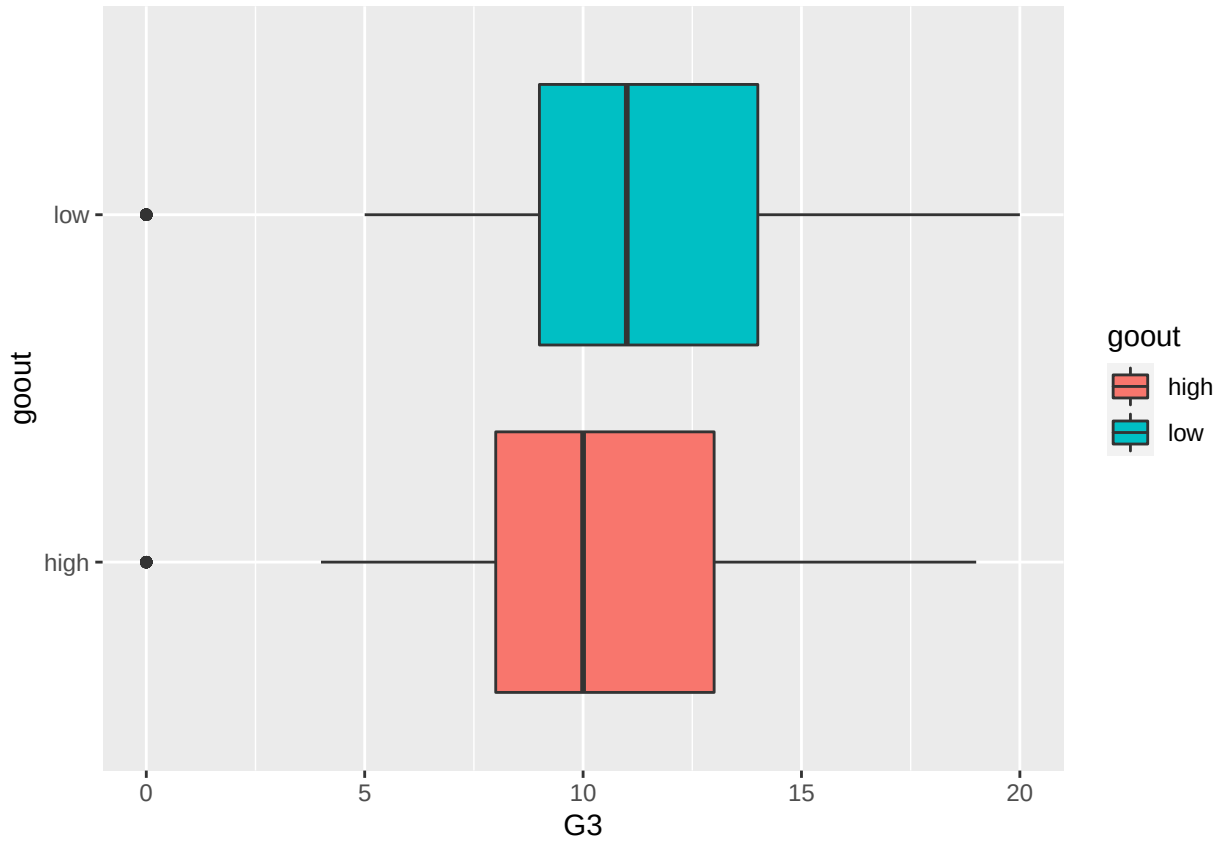

```
ggplot(data = data, aes(x = G3, y=romantic, fill = romantic)) +
  geom_boxplot()
```




```
ggplot(data = data, aes(x = G3, y=internet, fill = internet)) +
  geom_boxplot()
```




```
ggplot(data = data, aes(x = G3, y=goout, fill = goout)) +
  geom_boxplot()
```




From the initial explorations above, we can see a few possible trends. Students who had at least one of the following traits: failed a class previously, were a highly frequent absent student, frequently went out, without internet, were frequent drinkers on the weekend, were in romantic relationships, and were first generation students, on average had lower final grades than their counterparts.

```
names(data)
```

```
##  [1] "school"              "sex"                 "age"
##  [4] "address"             "famsize"             "Pstatus"
##  [7] "Medu"                "Fedu"                "Mjob"
## [10] "Fjob"                "reason"              "guardian"
## [13] "traveltime"          "studytime"           "failures"
## [16] "schoolsup"           "famsup"              "paid"
## [19] "activities"          "nursery"             "higher"
## [22] "internet"            "romantic"            "famrel"
## [25] "freetime"            "goout"               "Dalc"
## [28] "Walc"                "health"              "absences"
## [31] "G1"                  "G2"                  "G3"
## [34] "first_gen_college"   "stable_learning_env" "high_freq_absent"
## [37] "failed"
```

```
num_cols <- unlist(lapply(data, is.numeric))
quant_vars <- data[,num_cols]
cor(quant_vars)
```

```
##                    age        Medu         Fedu  traveltime    studytime
## age         1.000000000 -0.16365842 -0.163438069  0.07064072 -0.004140037
## Medu       -0.163658419  1.00000000  0.623455112 -0.17163930  0.064944137
## Fedu       -0.163438069  0.62345511  1.000000000 -0.15819405 -0.009174639
```

```
## traveltime  0.070640721 -0.17163930 -0.158194054  1.00000000 -0.100909119
## studytime  -0.004140037  0.06494414 -0.009174639 -0.10090912  1.000000000
## failures    0.243665377 -0.23667996 -0.250408444  0.09223875 -0.173563031
## absences    0.175230079  0.10028482  0.024472887 -0.01294378 -0.062700175
## G1         -0.064081497  0.20534100  0.190269936 -0.09303999  0.160611915
## G2         -0.143474049  0.21552717  0.164893393 -0.15319796  0.135879999
## G3         -0.161579438  0.21714750  0.152456939 -0.11714205  0.097819690
##               failures    absences          G1         G2          G3
## age         0.24366538  0.17523008 -0.06408150 -0.1434740 -0.16157944
## Medu       -0.23667996  0.10028482  0.20534100  0.2155272  0.21714750
## Fedu       -0.25040844  0.02447289  0.19026994  0.1648934  0.15245694
## traveltime  0.09223875 -0.01294378 -0.09303999 -0.1531980 -0.11714205
## studytime  -0.17356303 -0.06270018  0.16061192  0.1358800  0.09781969
## failures    1.00000000  0.06372583 -0.35471761 -0.3558956 -0.36041494
## absences    0.06372583  1.00000000 -0.03100290 -0.0317767  0.03424732
## G1         -0.35471761 -0.03100290  1.00000000  0.8521181  0.80146793
## G2         -0.35589563 -0.03177670  0.85211807  1.0000000  0.90486799
## G3         -0.36041494  0.03424732  0.80146793  0.9048680  1.00000000
```

```
#library(corr)
#quant_vars %>% correlate() %>% network_plot(min_cor=0.2)
```

### Splitting data into training and testing sets

```
data <- data %>%
  mutate(ord_g3 = factor(G3, ordered=T)
  )
data$ord_g3
```

```
##   [1] 6  6  10 15 10 15 11 6  19 15 9  12 14 11 16 14 14 10 5  10 15 15 16 12 8
##  [26] 8  11 15 11 11 12 17 16 12 15 6  18 15 11 13 11 12 18 11 9  6  11 20 14 7
##  [51] 13 13 10 11 13 10 15 15 9  16 11 11 9  9  10 15 12 6  8  16 15 10 5  14 11
##  [76] 10 10 11 10 5  12 11 6  15 10 8  6  14 10 7  8  18 6  10 14 10 15 10 14 8
## [101] 5  17 14 6  18 11 8  18 13 16 19 10 13 19 9  16 14 13 8  13 15 15 13 13 8
## [126] 12 11 9  0  18 0  0  12 11 0  0  0  0  12 15 0  9  11 13 0  11 0  11 0  10
## [151] 0  14 10 0  12 8  13 10 15 12 0  7  0  10 7  12 10 16 0  14 0  16 10 0  9
## [176] 9  11 6  9  11 8  12 17 8  12 11 11 15 9  10 13 9  8  10 14 15 16 10 18 10
## [201] 16 10 10 6  11 9  7  13 10 7  8  13 14 8  10 15 4  8  8  10 6  0  17 13 14
## [226] 7  15 12 9  12 14 11 9  13 6  10 13 12 11 0  12 12 0  12 0  18 13 8  5  15
## [251] 8  10 8  8  12 8  13 11 14 0  18 8  12 9  0  17 10 11 10 0  9  14 11 14 10
## [276] 12 9  9  8  10 8  10 12 10 11 11 19 12 14 15 11 15 13 18 14 11 0  8  14 16
## [301] 11 10 14 18 13 12 18 8  12 10 0  13 11 11 13 11 0  9  10 11 13 9  11 15 15
## [326] 11 16 10 9  14 8  14 0  0  0  15 13 0  17 10 11 0  15 0  10 14 16 9  15 13
## [351] 8  13 8  8  11 9  13 11 10 16 13 12 10 15 12 10 13 0  10 11 9  12 11 5  19
## [376] 10 15 10 15 10 14 7  10 0  5  10 6  0  8  0  9  16 7  10 9
## 18 Levels: 0 < 4 < 5 < 6 < 7 < 8 < 9 < 10 < 11 < 12 < 13 < 14 < 15 < ... < 20
```

```
attach(data)
set.seed(3)
train_ind <- sample(x = nrow(data), size = 0.8 * nrow(data))
test_ind_neg <- -train_ind
training <- data[train_ind, ]
testing <- data[test_ind_neg, ]
training
```

```
##     school sex age address famsize Pstatus Medu Fedu     Mjob     Fjob
## 261     GP   F  18       U     GT3       T    4    3 services    other
## 186     GP   M  17       U     GT3       T    3    3 services services
## 140     GP   F  15       U     GT3       T    4    4  teacher  teacher
## 36      GP   F  15       U     GT3       T    2    3    other    other
## 394     MS   M  18       R     LE3       T    3    2 services    other
## 363     MS   F  18       U     GT3       T    3    3 services services
## 276     GP   F  17       U     LE3       T    2    2 services    other
## 330     GP   F  17       U     GT3       T    4    4  teacher  teacher
## 183     GP   F  17       U     GT3       T    2    4 services services
## 168     GP   F  16       U     GT3       T    4    2   health services
## 48      GP   M  16       U     GT3       T    4    3   health services
## 104     GP   F  15       U     GT3       T    3    2 services    other
## 136     GP   F  15       U     GT3       T    4    4 services  at_home
## 37      GP   M  15       U     LE3       T    4    3  teacher services
## 108     GP   M  16       U     GT3       T    3    3 services    other
## 395     MS   M  19       U     LE3       T    1    1    other  at_home
## 165     GP   M  17       R     LE3       T    1    1    other services
## 137     GP   M  17       R     GT3       T    3    4  at_home    other
## 256     GP   M  17       U     LE3       T    1    1   health    other
## 376     MS   F  18       R     GT3       T    1    1    other    other
## 374     MS   F  17       R     GT3       T    1    2    other    other
## 274     GP   M  17       R     GT3       T    1    2  at_home  at_home
## 12      GP   F  15       U     GT3       T    2    1 services    other
## 40      GP   F  15       R     GT3       T    2    2  at_home    other
## 22      GP   M  15       U     GT3       T    4    4   health   health
## 70      GP   F  15       R     LE3       T    3    1    other    other
## 296     GP   M  17       U     GT3       T    3    3   health    other
## 15      GP   M  15       U     GT3       A    2    2    other    other
## 388     MS   F  19       R     GT3       T    2    3 services    other
## 75      GP   F  16       U     GT3       T    3    3    other services
## 29      GP   M  16       U     LE3       A    3    4 services    other
## 343     GP   M  18       U     LE3       T    3    4 services    other
## 131     GP   F  15       R     GT3       T    3    4 services  teacher
## 62      GP   F  16       U     GT3       T    1    1 services services
## 127     GP   F  15       U     LE3       A    3    4    other    other
## 101     GP   M  16       U     GT3       T    4    4 services services
## 247     GP   M  17       U     GT3       T    2    3    other    other
## 182     GP   M  16       U     GT3       T    3    3 services    other
## 383     MS   M  17       U     GT3       T    2    3    other services
## 138     GP   F  16       U     GT3       A    3    3    other    other
## 68      GP   F  16       U     GT3       T    3    1 services    other
## 33      GP   M  15       R     GT3       T    4    3  teacher  at_home
## 275     GP   F  17       U     GT3       T    2    4  at_home   health
## 166     GP   M  16       U     GT3       T    3    2 services services
## 185     GP   F  16       U     GT3       T    3    2    other    other
## 237     GP   M  17       U     LE3       T    2    2    other    other
## 192     GP   F  17       U     GT3       T    1    1  at_home services
## 391     MS   M  20       U     LE3       A    2    2 services services
## 65      GP   F  15       U     LE3       T    4    3 services services
## 9       GP   M  15       U     LE3       A    3    2 services    other
## 241     GP   M  17       U     LE3       T    4    3   health    other
## 105     GP   M  15       U     GT3       A    3    4 services    other
## 197     GP   M  17       U     GT3       T    4    4 services  teacher
```

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## 128     GP   F  19       U     GT3       T    0    1  at_home    other
## 198     GP   M  16       R     LE3       T    3    3  teacher    other
## 317     GP   F  18       U     GT3       T    2    1 services    other
## 171     GP   M  16       U     GT3       T    3    4    other    other
## 392     MS   M  17       U     LE3       T    3    1 services services
## 334     GP   F  18       U     LE3       T    2    2    other    other
## 73      GP   F  15       R     GT3       T    1    1    other    other
## 195     GP   M  16       U     GT3       T    2    3    other    other
## 204     GP   F  17       R     GT3       T    2    2    other    other
## 50      GP   F  15       U     GT3       T    4    4 services  teacher
## 145     GP   M  17       U     GT3       T    2    1    other    other
## 176     GP   M  17       U     LE3       T    4    3  teacher    other
## 164     GP   M  17       U     GT3       T    1    3  at_home services
## 352     MS   M  17       U     GT3       T    3    3   health    other
## 225     GP   F  16       U     GT3       T    4    4  teacher services
## 258     GP   M  19       U     LE3       A    4    3 services  at_home
## 117     GP   M  15       U     GT3       T    4    4    other  teacher
## 88      GP   F  15       U     GT3       T    4    2    other    other
## 359     MS   M  18       U     LE3       T    1    1    other services
## 71      GP   M  16       U     GT3       T    3    1    other    other
## 266     GP   M  18       R     LE3       A    3    4    other    other
## 102     GP   M  16       U     GT3       T    4    4 services  teacher
## 302     GP   M  17       U     LE3       T    4    4    other  teacher
## 19      GP   M  17       U     GT3       T    3    2 services services
## 47      GP   F  16       U     LE3       A    3    3    other services
## 161     GP   M  17       R     LE3       T    2    1  at_home    other
## 66      GP   F  16       U     LE3       T    4    3  teacher services
## 245     GP   F  18       U     GT3       T    2    1    other    other
## 303     GP   F  17       U     GT3       T    4    2    other    other
## 139     GP   M  16       U     LE3       T    1    1 services    other
## 218     GP   M  18       U     LE3       T    3    3 services   health
## 362     MS   M  18       R     LE3       T    1    1  at_home    other
## 4       GP   F  15       U     GT3       T    4    2   health services
## 16      GP   F  16       U     GT3       T    4    4   health    other
## 326     GP   M  18       U     GT3       T    4    4    other    other
## 262     GP   M  18       U     GT3       T    4    3  teacher    other
## 309     GP   M  19       R     GT3       T    3    3    other services
## 99      GP   F  16       U     GT3       T    4    4    other    other
## 393     MS   M  21       R     GT3       T    1    1    other    other
## 123     GP   F  16       U     LE3       T    2    4    other   health
## 365     MS   F  17       R     GT3       T    1    2    other services
## 10      GP   M  15       U     GT3       T    3    4    other    other
## 28      GP   M  15       U     GT3       T    4    2   health services
## 351     MS   M  19       R     GT3       T    1    1    other services
## 91      GP   F  16       U     GT3       T    3    3    other    other
## 114     GP   M  15       U     LE3       T    4    2  teacher    other
## 265     GP   F  18       U     GT3       T    2    2  at_home services
## 313     GP   M  19       U     GT3       T    1    2    other services
## 368     MS   F  17       R     GT3       T    1    1    other services
## 233     GP   M  17       U     GT3       T    4    4  teacher  teacher
## 206     GP   F  17       U     GT3       T    3    4  at_home services
## 7       GP   M  16       U     LE3       T    2    2    other    other
## 332     GP   F  17       R     GT3       T    2    4  at_home    other
## 222     GP   F  17       U     GT3       T    1    1  at_home    other
```

```
## 109     GP   M  15       R     GT3       T    4    4    other    other
## 252     GP   M  16       U     GT3       T    3    3  at_home    other
## 348     GP   M  18       U     GT3       T    4    3  teacher    other
## 232     GP   M  17       R     GT3       T    2    2    other    other
## 346     GP   F  18       U     GT3       T    3    2    other services
## 55      GP   F  15       U     LE3       A    3    3    other    other
## 259     GP   M  18       U     GT3       T    2    1    other    other
## 373     MS   F  17       U     GT3       T    2    2    other  at_home
## 193     GP   M  17       U     GT3       T    1    2  at_home services
## 112     GP   F  16       R     GT3       T    3    3 services    other
## 44      GP   M  15       U     GT3       T    2    2 services services
## 354     MS   M  19       R     GT3       T    1    1    other    other
## 53      GP   M  15       U     LE3       A    4    2   health   health
## 13      GP   M  15       U     LE3       T    4    4   health services
## 110     GP   F  16       U     LE3       T    4    4   health   health
## 14      GP   M  15       U     GT3       T    4    3  teacher    other
## 377     MS   F  20       U     GT3       T    4    2   health    other
## 85      GP   F  15       U     GT3       T    1    1    other    other
## 179     GP   M  16       R     GT3       T    4    2  teacher services
## 163     GP   M  16       U     LE3       T    1    2    other    other
## 272     GP   F  18       U     GT3       T    2    3    other services
## 205     GP   F  16       R     GT3       T    2    2 services services
## 113     GP   F  16       U     GT3       T    2    2  at_home    other
## 228     GP   M  17       U     LE3       T    2    3 services services
## 170     GP   F  16       U     GT3       T    4    4   health   health
## 8       GP   F  17       U     GT3       A    4    4    other  teacher
## 327     GP   M  17       U     GT3       T    3    3    other services
## 319     GP   F  17       R     GT3       T    3    4  at_home services
## 201     GP   F  16       U     GT3       T    4    3   health    other
## 74      GP   M  16       U     GT3       T    3    1    other    other
## 49      GP   M  15       U     GT3       T    4    2  teacher    other
## 151     GP   M  18       U     LE3       T    1    1    other    other
## 338     GP   F  17       U     GT3       T    3    2    other    other
## 253     GP   M  18       U     GT3       T    2    1 services services
## 35      GP   M  16       U     GT3       T    3    2    other    other
## 308     GP   M  19       U     GT3       T    4    4  teacher services
## 321     GP   F  17       U     GT3       A    4    3 services services
## 125     GP   F  16       U     GT3       T    2    2    other    other
## 310     GP   F  19       U     LE3       T    1    1  at_home    other
## 324     GP   F  17       U     GT3       T    3    1 services services
## 2       GP   F  17       U     GT3       T    1    1  at_home    other
## 100     GP   F  16       U     GT3       T    4    3    other  at_home
## 372     MS   M  18       R     LE3       T    1    2  at_home services
## 325     GP   F  17       U     LE3       T    0    2  at_home  at_home
## 367     MS   M  18       U     LE3       T    4    4  teacher services
## 84      GP   M  15       U     LE3       T    2    2 services services
## 90      GP   M  16       U     LE3       A    4    4  teacher   health
## 314     GP   F  19       U     LE3       T    3    2 services    other
## 267     GP   M  17       U     GT3       T    3    1 services    other
## 153     GP   F  15       R     GT3       T    3    3 services services
## 350     MS   M  18       R     GT3       T    3    2    other    other
## 211     GP   F  19       U     GT3       T    3    3    other    other
## 342     GP   M  18       U     GT3       T    4    4  teacher services
## 217     GP   F  17       U     GT3       T    4    3    other    other
```

```
## 370     MS   F  18       R     GT3       T    4    4    other  teacher
## 208     GP   F  16       U     GT3       T    4    3  teacher    other
## 67      GP   M  15       U     GT3       A    4    4    other services
## 162     GP   M  15       R     GT3       T    3    2    other    other
## 255     GP   M  17       R     GT3       T    2    1    other    other
## 301     GP   F  18       U     LE3       A    4    4   health    other
## 289     GP   M  18       U     GT3       T    2    1 services services
## 52      GP   F  15       U     LE3       T    4    2   health    other
## 45      GP   F  16       U     LE3       T    2    2    other  at_home
## 333     GP   F  18       U     GT3       T    3    3 services services
## 345     GP   F  18       U     GT3       T    2    3  at_home    other
## 316     GP   F  19       R     GT3       T    2    3    other    other
## 277     GP   F  18       R     GT3       A    3    2    other services
## 189     GP   F  17       U     GT3       A    3    3   health    other
## 63      GP   F  16       U     LE3       T    1    2    other services
## 142     GP   M  16       U     LE3       T    2    2 services services
## 106     GP   F  15       U     GT3       A    3    3    other   health
## 384     MS   M  19       R     GT3       T    1    1    other services
## 122     GP   M  15       U     GT3       T    2    2 services services
## 263     GP   M  18       R     GT3       T    3    2    other    other
## 297     GP   F  19       U     GT3       T    4    4   health    other
## 306     GP   F  18       U     GT3       T    2    4 services  at_home
## 87      GP   F  16       U     LE3       T    2    2  at_home    other
## 121     GP   F  15       U     GT3       T    1    2  at_home services
## 6       GP   M  16       U     LE3       T    4    3 services    other
## 293     GP   F  18       U     LE3       T    2    1 services  at_home
## 356     MS   F  18       U     GT3       T    3    3 services services
## 81      GP   M  15       U     GT3       T    2    3    other services
## 246     GP   M  16       U     GT3       T    2    1    other    other
## 209     GP   F  16       U     GT3       T    1    1  at_home    other
## 39      GP   F  15       R     GT3       T    3    4 services   health
## 147     GP   F  15       U     GT3       T    3    2   health services
## 219     GP   F  17       U     GT3       T    2    3  at_home    other
## 169     GP   F  16       U     GT3       T    2    2    other    other
## 268     GP   F  18       R     GT3       T    4    4  teacher    other
## 278     GP   M  18       U     GT3       T    4    4  teacher services
## 210     GP   F  17       R     GT3       T    4    3  teacher    other
## 124     GP   M  16       U     GT3       T    4    4   health    other
## 20      GP   M  16       U     LE3       T    4    3   health    other
## 5       GP   F  16       U     GT3       T    3    3    other    other
## 203     GP   F  17       U     GT3       T    1    1    other    other
## 236     GP   M  16       U     GT3       T    3    2  at_home    other
## 135     GP   M  15       R     GT3       T    3    4  at_home  teacher
## 177     GP   F  16       U     GT3       T    2    2 services    other
## 69      GP   F  15       R     LE3       T    2    2   health services
## 291     GP   M  18       U     GT3       T    4    2  teacher    other
## 380     MS   F  17       R     GT3       T    3    1  at_home    other
## 299     GP   F  18       U     GT3       T    4    3    other    other
## 311     GP   F  19       U     LE3       T    1    2 services services
## 202     GP   F  16       U     GT3       T    2    3    other    other
## 146     GP   F  15       U     GT3       T    1    1    other services
## 223     GP   F  16       U     GT3       T    2    3 services  teacher
## 390     MS   F  18       U     GT3       T    1    1    other    other
## 181     GP   M  16       U     GT3       T    4    3  teacher    other
```

```
## 312     GP   F  19       U     GT3       T    2    1  at_home    other
## 242     GP   M  17       R     LE3       A    4    4  teacher    other
## 158     GP   F  18       R     GT3       T    1    1  at_home    other
## 382     MS   M  18       R     GT3       T    2    1    other    other
## 42      GP   M  15       U     LE3       T    4    4  teacher    other
## 24      GP   M  16       U     LE3       T    2    2    other    other
## 173     GP   M  17       U     LE3       T    4    4  teacher    other
## 294     GP   F  17       R     LE3       T    3    1 services    other
## 159     GP   M  16       R     GT3       T    2    2  at_home    other
## 323     GP   F  17       R     LE3       T    2    2 services services
## 129     GP   M  18       R     GT3       T    2    2 services    other
## 290     GP   M  18       U     LE3       A    4    4  teacher  teacher
## 79      GP   M  17       U     GT3       T    2    1    other    other
## 286     GP   M  17       U     GT3       T    1    1    other    other
## 331     GP   M  18       U     LE3       T    2    2    other    other
## 144     GP   F  16       U     LE3       T    1    1  at_home  at_home
## 41      GP   F  16       U     LE3       T    2    2    other    other
## 118     GP   M  16       U     GT3       T    3    3    other services
## 51      GP   F  16       U     LE3       T    2    2 services services
## 344     GP   F  17       U     GT3       A    2    2  at_home  at_home
## 361     MS   F  18       R     LE3       A    1    4  at_home    other
## 349     GP   F  17       U     GT3       T    4    3   health    other
## 387     MS   F  18       R     GT3       T    4    4  teacher  at_home
## 83      GP   F  15       U     LE3       T    3    2 services    other
## 381     MS   M  18       U     GT3       T    4    4  teacher  teacher
## 375     MS   F  18       R     LE3       T    4    4    other    other
## 64      GP   F  16       U     GT3       T    4    3  teacher   health
## 280     GP   M  18       U     LE3       T    4    3  teacher services
## 270     GP   F  18       R     GT3       T    2    1    other    other
## 23      GP   M  16       U     LE3       T    4    2  teacher    other
## 27      GP   M  15       U     GT3       T    2    2    other    other
## 230     GP   F  17       U     GT3       A    2    1    other    other
## 172     GP   M  16       U     GT3       T    1    0    other    other
## 26      GP   F  16       U     GT3       T    2    2 services services
## 251     GP   M  18       U     GT3       T    3    2 services    other
## 86      GP   F  15       U     GT3       T    4    4 services services
## 184     GP   F  17       U     LE3       T    3    3    other    other
## 360     MS   F  18       U     LE3       T    1    1  at_home services
## 335     GP   F  18       R     GT3       T    2    2  at_home    other
## 307     GP   M  20       U     GT3       A    3    2 services    other
## 248     GP   M  22       U     GT3       T    3    1 services services
## 357     MS   F  17       R     GT3       T    4    4  teacher services
## 339     GP   F  18       U     LE3       T    3    3 services services
## 132     GP   F  15       U     GT3       T    1    1  at_home    other
## 111     GP   M  15       U     LE3       A    4    4  teacher  teacher
## 199     GP   F  17       U     GT3       T    4    4 services  teacher
## 207     GP   F  16       U     GT3       A    3    1 services    other
## 141     GP   M  15       U     GT3       T    4    3  teacher services
## 298     GP   F  18       U     LE3       T    4    3    other    other
## 77      GP   M  15       U     GT3       T    4    0  teacher    other
## 355     MS   M  17       R     GT3       T    4    3 services    other
## 257     GP   F  17       U     LE3       T    4    2  teacher services
## 318     GP   F  18       U     GT3       T    4    3    other    other
## 38      GP   M  16       R     GT3       A    4    4    other  teacher
```

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## 216     GP   F  17       U     LE3       T    3    2    other    other
## 92      GP   F  15       U     GT3       T    4    3 services    other
## 379     MS   F  18       U     GT3       T    3    3    other    other
## 190     GP   M  17       R     GT3       T    1    2  at_home    other
## 305     GP   M  19       U     GT3       T    3    3    other    other
## 103     GP   M  15       U     GT3       T    4    4 services    other
## 320     GP   F  18       U     GT3       T    4    4  teacher    other
## 57      GP   F  15       U     GT3       A    4    3 services services
## 353     MS   M  18       U     LE3       T    1    3  at_home services
## 61      GP   F  16       R     GT3       T    4    4   health  teacher
## 134     GP   F  16       U     GT3       A    3    4 services    other
## 220     GP   F  17       U     GT3       T    2    2  at_home  at_home
## 287     GP   F  18       U     GT3       T    2    2  at_home  at_home
## 167     GP   M  16       U     GT3       T    2    2    other    other
## 1       GP   F  18       U     GT3       A    4    4  at_home  teacher
## 215     GP   F  17       R     LE3       T    4    4 services    other
## 3       GP   F  15       U     LE3       T    1    1  at_home    other
## 30      GP   M  16       U     GT3       T    4    4  teacher  teacher
## 82      GP   M  15       U     GT3       T    2    3    other    other
## 143     GP   F  15       U     GT3       T    4    4  teacher services
## 93      GP   F  16       U     LE3       T    3    1    other    other
## 337     GP   F  19       R     GT3       A    3    1 services  at_home
## 221     GP   F  17       R     GT3       T    2    1  at_home services
## 364     MS   F  17       U     LE3       T    4    4  at_home  at_home
## 96      GP   F  15       R     GT3       T    1    1  at_home    other
## 126     GP   M  15       U     GT3       T    3    4 services services
## 214     GP   M  18       U     GT3       T    2    2 services    other
## 188     GP   M  16       U     LE3       T    2    1    other    other
## 285     GP   F  17       U     GT3       T    2    2    other    other
## 371     MS   F  19       U     LE3       T    3    2 services services
## 271     GP   F  19       U     GT3       T    3    3    other services
## 295     GP   M  18       R     LE3       T    3    2 services    other
## 157     GP   M  17       R     LE3       T    1    2    other    other
## 25      GP   F  15       R     GT3       T    2    4 services   health
## 212     GP   M  17       U     LE3       T    4    4 services    other
## 238     GP   F  16       U     GT3       T    2    1    other    other
## 156     GP   M  15       R     GT3       T    2    3  at_home services
## 213     GP   F  16       U     GT3       A    2    2    other    other
## 148     GP   F  15       U     GT3       T    1    2  at_home    other
## 234     GP   M  16       U     GT3       T    4    4   health    other
## 56      GP   F  16       U     GT3       A    2    1    other    other
## 107     GP   F  15       U     GT3       T    2    2    other    other
## 154     GP   M  19       U     GT3       T    3    2 services  at_home
## 191     GP   F  16       U     GT3       T    2    3 services services
## 249     GP   M  18       R     LE3       T    3    3    other services
## 366     MS   M  18       R     GT3       T    1    3  at_home    other
## 54      GP   F  15       U     GT3       T    4    4 services services
##         reason guardian traveltime studytime failures schoolsup famsup paid
## 261       home   father          1         2        0        no    yes  yes
## 186      other   mother          1         2        0        no    yes   no
## 140     course   mother          2         1        0        no     no   no
## 36       other   father          2         1        0        no    yes   no
## 394     course   mother          3         1        0        no     no   no
## 363      other   mother          2         2        0        no    yes   no
```

```
## 276     course   mother          2         2         0       yes    yes  yes
## 330     course   mother          2         3         0        no    yes  yes
## 183 reputation   father          1         2         0        no    yes   no
## 168       home   father          1         2         0        no     no  yes
## 48  reputation   mother          1         4         0        no     no   no
## 104       home   mother          2         2         0       yes    yes  yes
## 136     course   mother          1         3         0        no    yes   no
## 37        home   mother          1         3         0        no    yes   no
## 108       home   father          1         3         0        no    yes   no
## 395     course   father          1         1         0        no     no   no
## 165     course   mother          4         2         3        no     no   no
## 137     course   mother          3         2         0        no     no   no
## 256     course   mother          2         1         1        no    yes   no
## 376       home   mother          4         3         0        no     no   no
## 374     course   mother          1         1         0        no     no   no
## 274       home   mother          1         2         0        no    yes  yes
## 12  reputation   father          3         3         0        no    yes   no
## 40  reputation   mother          1         1         0       yes    yes  yes
## 22       other   father          1         1         0        no    yes  yes
## 70  reputation   father          2         4         0        no    yes   no
## 296       home   mother          1         1         0        no    yes  yes
## 15        home    other          1         3         0        no    yes   no
## 388     course   mother          1         3         1        no     no   no
## 75        home   mother          1         2         0       yes    yes  yes
## 29        home   mother          1         2         0       yes    yes   no
## 343       home   mother          1         2         0        no     no   no
## 131     course   father          2         3         2        no    yes   no
## 62      course   father          4         1         0       yes    yes   no
## 127       home   mother          1         2         0       yes     no   no
## 101      other   mother          1         1         0       yes    yes  yes
## 247     course   father          2         1         0        no     no   no
## 182       home   mother          1         2         0        no     no  yes
## 383       home   father          2         2         0        no     no   no
## 138     course    other          2         1         2        no    yes   no
## 68      course   mother          1         4         0       yes    yes  yes
## 33      course   mother          1         2         0        no    yes   no
## 275 reputation   mother          2         2         0        no    yes  yes
## 166     course   mother          2         1         1        no    yes   no
## 185 reputation   mother          1         2         0        no    yes  yes
## 237       home   father          1         2         0        no     no  yes
## 192     course   mother          1         2         0        no     no   no
## 391     course    other          1         2         2        no    yes  yes
## 65  reputation   father          1         2         0       yes     no   no
## 9         home   mother          1         2         0        no    yes  yes
## 241     course   mother          2         2         0        no     no   no
## 105     course   mother          1         2         0        no    yes  yes
## 197       home   mother          1         1         0        no     no   no
## 128     course    other          1         2         3        no    yes   no
## 198       home   father          3         1         0        no    yes  yes
## 317     course   mother          2         2         0        no    yes  yes
## 171     course   father          3         1         2        no    yes   no
## 392     course   mother          2         1         0        no     no   no
## 334       home    other          1         2         0        no     no   no
## 73  reputation   mother          1         2         2       yes    yes   no
```

```
## 195       home   father          2         1         0        no     no   no
## 204 reputation   mother          1         1         0        no    yes   no
## 50       other   father          1         2         1       yes    yes   no
## 145       home   mother          1         1         3        no    yes   no
## 176     course   mother          2         2         0        no     no  yes
## 164     course   father          1         1         0        no     no   no
## 352     course   mother          2         2         0        no    yes  yes
## 225       home   mother          1         3         0        no    yes   no
## 258 reputation   mother          1         2         0        no    yes   no
## 117 reputation   father          2         2         0        no    yes   no
## 88  reputation   mother          1         3         0        no    yes   no
## 359       home   father          2         1         0        no     no   no
## 71  reputation   father          2         4         0        no    yes  yes
## 266 reputation   mother          2         2         0        no    yes  yes
## 102      other   father          1         3         0        no    yes   no
## 302       home   father          2         1         0        no     no  yes
## 19      course   mother          1         1         3        no    yes   no
## 47        home   mother          1         2         0        no    yes   no
## 161     course   mother          2         1         2        no     no   no
## 66      course   mother          3         2         0        no    yes   no
## 245     course    other          2         3         0        no    yes  yes
## 303 reputation   mother          2         3         0        no    yes  yes
## 139     course   mother          1         2         1        no     no   no
## 218       home   father          1         2         1        no    yes  yes
## 362      other   mother          2         2         1        no     no   no
## 4         home   mother          1         3         0        no    yes  yes
## 16        home   mother          1         1         0        no    yes   no
## 326     course   mother          1         3         0        no     no   no
## 262     course   mother          1         2         0        no    yes  yes
## 309 reputation   father          1         2         1        no     no   no
## 99  reputation   mother          1         1         0        no     no   no
## 393     course    other          1         1         3        no     no   no
## 123     course   father          2         2         0        no    yes  yes
## 365     course   father          2         2         0        no     no   no
## 10        home   mother          1         2         0        no    yes  yes
## 28       other   mother          1         1         0        no     no  yes
## 351       home    other          3         2         3        no     no   no
## 91        home   mother          1         3         0        no    yes  yes
## 114     course   mother          1         1         0        no     no   no
## 265       home   mother          1         3         0        no    yes  yes
## 313     course    other          1         2         1        no     no   no
## 368 reputation   mother          3         1         1        no    yes  yes
## 233 reputation   mother          1         2         0       yes    yes   no
## 206       home   mother          1         3         1        no    yes  yes
## 7         home   mother          1         2         0        no     no   no
## 332     course   father          1         3         0        no    yes   no
## 222 reputation   mother          1         3         1        no    yes   no
## 109       home   father          4         4         0        no    yes  yes
## 252 reputation    other          3         2         0       yes    yes   no
## 348     course   mother          1         3         0        no    yes  yes
## 232     course   father          2         2         0        no    yes  yes
## 346      other   mother          1         3         0        no     no   no
## 55       other   mother          1         1         0        no     no  yes
## 259       home   mother          1         2         0        no     no   no
```

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## 373       home   mother          1          3          0        no     no   no
## 193      other    other          2          2          0        no     no  yes
## 112 reputation   father          1          3          1       yes    yes   no
## 44       course   father          1          1          0       yes    yes   no
## 354       home    other          3          1          1        no    yes   no
## 53       other   father          2          1          1        no     no   no
## 13       course   father          1          1          0        no    yes  yes
## 110      other   mother          1          3          0        no    yes  yes
## 14       course   mother          2          2          0        no    yes  yes
## 377      course    other          2          3          2        no    yes  yes
## 85        home   father          1          2          0        no    yes   no
## 179      other   mother          1          1          0        no    yes   no
## 163      course   mother          2          1          1        no     no   no
## 272 reputation   father          1          4          0        no    yes  yes
## 205 reputation   mother          2          4          0        no    yes  yes
## 113       home   mother          1          2          1       yes     no   no
## 228 reputation   father          1          2          0        no    yes  yes
## 170 reputation   mother          1          2          0        no    yes  yes
## 8         home   mother          2          2          0       yes    yes   no
## 327 reputation   mother          1          1          0        no     no   no
## 319      course   father          1          3          0        no    yes  yes
## 201       home   mother          1          2          0        no    yes   no
## 74  reputation   mother          1          1          0        no     no   no
## 49        home   mother          1          2          0        no    yes  yes
## 151      course   mother          1          1          3        no     no   no
## 338       home   mother          1          2          0        no    yes  yes
## 253      other   mother          1          1          1        no     no   no
## 35        home   mother          1          1          0        no    yes  yes
## 308 reputation    other          2          1          1        no    yes  yes
## 321      course   mother          1          2          0        no    yes  yes
## 125       home   mother          1          2          0        no     no  yes
## 310 reputation    other          1          2          1       yes    yes   no
## 324      course   father          1          3          0        no    yes   no
## 2        course   father          1          2          0        no    yes   no
## 100      course   mother          1          3          0       yes    yes  yes
## 372       other   father          3          1          0        no    yes  yes
## 325       home   father          2          3          0        no     no   no
## 367       other   mother          2          3          0        no     no  yes
## 84        home   mother          2          2          0        no     no  yes
## 90  reputation   mother          1          2          0        no    yes   no
## 314 reputation    other          2          2          1        no    yes  yes
## 267       other   mother          1          2          0        no     no  yes
## 153 reputation    other          2          3          2        no    yes  yes
## 350      course   mother          2          1          1        no    yes   no
## 211 reputation    other          1          4          0        no    yes  yes
## 342       home   father          1          2          1        no    yes   no
## 217 reputation   mother          1          2          2        no     no  yes
## 370       other   father          3          2          0        no    yes  yes
## 208       other   mother          1          2          0        no     no  yes
## 67  reputation   mother          1          4          0        no    yes   no
## 162      course   mother          2          2          2       yes    yes   no
## 255      course   mother          1          1          0        no     no   no
## 301       home   mother          1          2          0        no    yes   no
## 289 reputation   mother          1          3          0        no     no  yes
```

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## 52       other   mother         1         2         0        no    yes  yes
## 45      course   father         2         2         1       yes     no   no
## 333       home   mother         1         2         0        no     no   no
## 345     course   mother         1         3         0        no    yes   no
## 316 reputation    other         1         3         1        no     no   no
## 277       home   mother         2         2         0        no     no   no
## 189 reputation   mother         1         2         0        no    yes   no
## 63  reputation   father         1         2         0       yes     no   no
## 142 reputation   father         2         1         2        no    yes   no
## 106 reputation   father         1         4         0       yes     no   no
## 384      other   mother         2         1         1        no     no   no
## 122       home   father         1         4         0        no    yes  yes
## 263     course   mother         1         3         0        no     no   no
## 297 reputation    other         2         2         0        no    yes  yes
## 306 reputation    other         1         2         1        no    yes  yes
## 87      course   mother         1         2         0        no    yes   no
## 121     course   mother         1         2         0        no     no   no
## 6   reputation   mother         1         2         0        no    yes  yes
## 293 reputation   mother         1         2         1        no     no   no
## 356     course   father         1         2         0        no    yes   no
## 81      course   father         1         1         0       yes    yes  yes
## 246     course   mother         3         1         0        no     no   no
## 209       home   mother         2         1         0        no    yes  yes
## 39      course   mother         1         3         0       yes    yes  yes
## 147       home   father         1         2         3        no    yes   no
## 219       home   father         2         1         0        no    yes  yes
## 169       home   mother         1         2         0        no    yes  yes
## 268 reputation   mother         2         2         0        no     no  yes
## 278       home   mother         2         1         0        no     no  yes
## 210 reputation   mother         2         3         0        no    yes  yes
## 124     course   mother         1         1         0        no    yes   no
## 20        home   father         1         1         0        no     no  yes
## 5         home   father         1         2         0        no    yes  yes
## 203     course   mother         1         2         0        no    yes  yes
## 236 reputation   mother         2         3         0        no     no   no
## 135     course   mother         4         2         0        no    yes   no
## 177 reputation   mother         2         2         0        no     no  yes
## 69  reputation   mother         2         2         0       yes    yes  yes
## 291       home   mother         1         2         0        no    yes  yes
## 380 reputation   mother         1         2         0        no    yes  yes
## 299 reputation   father         1         4         0        no    yes  yes
## 311       home    other         1         2         1        no     no   no
## 202 reputation   mother         1         2         0       yes    yes  yes
## 146     course   father         1         2         0        no    yes  yes
## 223      other   mother         1         2         0       yes     no   no
## 390     course   mother         2         2         1        no     no   no
## 181       home   mother         1         2         0        no    yes  yes
## 312      other    other         3         2         0        no    yes   no
## 242     course   mother         2         2         0        no    yes  yes
## 158     course   mother         3         1         3        no    yes   no
## 382      other   mother         2         1         0        no     no   no
## 42        home    other         1         1         0        no    yes   no
## 24  reputation   mother         2         2         0        no    yes   no
## 173 reputation   mother         1         2         0        no    yes  yes
```

```
## 294 reputation   mother          2         4         0        no    yes  yes
## 159     course   mother          3         1         0        no     no   no
## 323     course   mother          1         3         0        no    yes  yes
## 129 reputation   mother          1         1         2        no    yes   no
## 290 reputation   mother          1         2         0        no    yes  yes
## 79        home   mother          2         1         3       yes    yes   no
## 286 reputation   father          1         2         0        no     no  yes
## 331     course   mother          1         4         0        no    yes   no
## 144     course   mother          1         1         0        no     no   no
## 41        home   mother          2         2         1        no    yes   no
## 118       home   father          2         1         0        no     no   no
## 51      course   mother          3         2         0        no    yes  yes
## 344       home   father          1         2         1        no    yes   no
## 361     course   mother          3         2         0        no     no   no
## 349 reputation   mother          1         3         0        no    yes  yes
## 387 reputation   mother          3         1         0        no    yes  yes
## 83  reputation   mother          1         2         0        no    yes  yes
## 381       home   father          1         2         0        no     no  yes
## 375 reputation   mother          2         3         0        no     no   no
## 64        home   mother          1         3         0       yes    yes  yes
## 280     course   mother          2         1         0        no     no  yes
## 270 reputation   mother          2         2         0        no    yes   no
## 23      course   mother          1         2         0        no     no   no
## 27        home   mother          1         1         0        no    yes  yes
## 230     course   mother          2         3         0        no     no   no
## 172 reputation   mother          2         2         0        no    yes  yes
## 26        home   mother          1         1         2        no    yes  yes
## 251     course   mother          2         1         1        no     no   no
## 86  reputation   father          2         2         2        no     no  yes
## 184 reputation   mother          1         2         0        no    yes   no
## 360     course   father          2         3         0        no     no   no
## 335     course   mother          2         4         0        no     no   no
## 307     course    other          1         1         0        no     no   no
## 248      other   mother          1         1         3        no     no   no
## 357      other   father          2         2         0        no    yes  yes
## 339       home   mother          1         4         0        no    yes   no
## 132     course   mother          3         1         0        no    yes   no
## 111     course   mother          1         1         0        no     no   no
## 199       home   mother          2         1         1        no    yes   no
## 207     course   mother          1         2         3        no    yes  yes
## 141     course   father          2         4         0       yes    yes   no
## 298       home    other          2         2         0        no    yes  yes
## 77      course   mother          2         4         0        no     no   no
## 355       home   mother          2         2         0        no    yes  yes
## 257 reputation   mother          1         4         0        no    yes  yes
## 318     course   mother          1         3         0        no    yes  yes
## 38  reputation   mother          2         3         0        no    yes   no
## 216 reputation   mother          2         2         0        no     no  yes
## 92  reputation   mother          1         1         0        no     no  yes
## 379       home   mother          1         2         0        no     no  yes
## 190       home   mother          1         2         0        no     no   no
## 305       home    other          1         2         1        no    yes   no
## 103     course   mother          1         1         0        no    yes   no
## 320     course   mother          1         2         0        no    yes  yes
```

```
##        reason guardian traveltime studytime failures schoolsup famsup
## 57  reputation   mother          1         2        0        no    yes
## 353     course   mother          1         1        1        no     no
## 61       other   mother          1         2        0        no    yes
## 134     course   father          1         1        0        no     no
## 220     course   mother          1         3        0        no    yes
## 287      other   mother          1         3        0        no    yes
## 167     course   father          1         2        0        no     no
## 1       course   mother          2         2        0       yes     no
## 215      other   mother          1         1        0        no    yes
## 3        other   mother          1         2        3       yes     no
## 30        home   mother          1         2        0        no    yes
## 82        home   mother          1         3        0       yes     no
## 143     course   mother          1         3        0        no    yes
## 93        home   father          1         2        0       yes    yes
## 337       home    other          1         3        1        no     no
## 221 reputation   mother          2         2        0        no    yes
## 364     course   mother          1         2        0        no    yes
## 96        home   mother          2         4        1       yes    yes
## 126       home   father          1         1        0       yes     no
## 214       home   mother          1         2        1        no    yes
## 188     course   mother          1         2        0        no     no
## 285     course   mother          1         2        0        no    yes
## 371       home    other          2         2        2        no     no
## 271       home    other          1         2        2        no    yes
## 295 reputation   mother          2         3        0        no    yes
## 157 reputation   mother          1         1        0        no     no
## 25      course   mother          1         3        0       yes    yes
## 212       home   mother          1         2        0        no    yes
## 238       home   mother          1         1        0        no     no
## 156     course   mother          1         2        0       yes     no
## 213 reputation   mother          1         2        0       yes    yes
## 148     course   mother          1         2        0        no    yes
## 234 reputation   father          1         2        0        no    yes
## 56       other   mother          1         2        0        no     no
## 107     course   mother          1         4        0       yes    yes
## 154       home   mother          1         1        3        no    yes
## 191     course   mother          1         2        0        no     no
## 249     course   mother          1         2        1        no    yes
## 366     course   mother          2         2        0        no    yes
## 54      course   mother          1         1        0       yes    yes
##     activities nursery higher internet romantic famrel freetime goout Dalc
## 261         no     yes    yes      yes      yes    low      low   low  low
## 186        yes     yes    yes      yes      yes   high      low  high  low
## 140        yes     yes    yes      yes       no   high      low   low  low
## 36         yes     yes    yes       no       no    low     high   low  low
## 394         no      no    yes      yes       no   high     high   low  low
## 363         no     yes    yes      yes      yes   high      low   low  low
## 276         no     yes    yes      yes      yes   high     high  high  low
## 330         no      no    yes      yes      yes   high      low   low  low
## 183        yes     yes    yes       no       no   high     high   low  low
## 168         no     yes    yes      yes      yes   high      low   low  low
## 48         yes     yes    yes      yes       no   high      low   low  low
## 104         no     yes    yes      yes       no   high      low  high  low
## 136        yes     yes    yes      yes      yes   high      low   low  low
##     Walc
## 261  low
## 186  low
## 140  low
## 36   low
## 394 high
## 363  low
## 276  low
## 330  low
## 183  low
## 168  low
## 48   low
## 104  low
## 136  low
```

```
## 37        yes     yes    yes      yes       no   high     high   low  low  low
## 108       yes     yes    yes      yes       no   high      low   low  low  low
## 395        no     yes    yes      yes       no    low      low   low  low  low
## 165       yes     yes     no       no      yes   high      low  high  low high
## 137        no     yes    yes       no       no   high     high  high  low high
## 256       yes     yes    yes      yes       no   high     high  high  low  low
## 376        no     yes    yes      yes       no   high      low   low  low  low
## 374       yes     yes    yes      yes       no    low     high  high  low  low
## 274       yes      no    yes       no      yes    low     high   low  low  low
## 12        yes     yes    yes      yes       no   high      low   low  low  low
## 40        yes     yes    yes       no       no   high      low   low  low  low
## 22         no     yes    yes      yes       no   high     high   low  low  low
## 70         no      no    yes      yes       no   high     high   low  low  low
## 296        no     yes    yes      yes       no   high     high   low  low  low
## 15         no     yes    yes      yes      yes   high     high   low  low  low
## 388       yes      no    yes      yes       no   high     high   low  low  low
## 75        yes     yes    yes      yes       no   high      low   low  low high
## 29        yes     yes    yes      yes       no   high      low   low  low  low
## 343       yes     yes    yes      yes      yes   high      low   low  low  low
## 131        no     yes    yes      yes      yes   high      low   low  low  low
## 62        yes      no    yes      yes      yes   high     high  high high high
## 127       yes     yes    yes      yes      yes   high      low   low  low  low
## 101       yes     yes    yes      yes       no   high     high  high high high
## 247        no     yes    yes      yes       no   high      low   low  low  low
## 182       yes     yes    yes      yes      yes   high      low   low  low  low
## 383       yes     yes    yes      yes       no   high     high   low  low  low
## 138       yes      no    yes      yes      yes   high      low   low  low  low
## 68         no     yes    yes      yes       no   high      low   low  low  low
## 33        yes     yes    yes      yes      yes   high     high   low  low  low
## 275        no     yes    yes      yes      yes   high      low   low  low  low
## 166       yes      no     no       no       no   high     high   low  low  low
## 185        no     yes    yes      yes       no    low      low   low  low  low
## 237       yes      no    yes      yes      yes   high     high   low high high
## 192       yes     yes    yes      yes       no   high      low   low  low  low
## 391        no     yes    yes       no       no   high     high  high high high
## 65        yes     yes    yes      yes      yes   high     high  high  low high
## 9          no     yes    yes      yes       no   high      low   low  low  low
## 241       yes     yes    yes      yes      yes    low     high  high  low high
## 105       yes     yes    yes      yes       no   high     high  high  low  low
## 197        no     yes    yes      yes       no   high      low   low  low  low
## 128        no      no     no       no       no    low     high   low  low  low
## 198       yes     yes    yes      yes       no    low      low  high  low high
## 317       yes     yes    yes      yes       no   high      low   low  low  low
## 171       yes      no    yes      yes       no    low     high  high  low high
## 392        no      no    yes      yes       no    low     high  high  low high
## 334       yes      no    yes      yes      yes   high      low   low  low  low
## 73         no      no    yes      yes      yes    low      low  high  low high
## 195        no     yes    yes      yes       no   high      low   low  low  low
## 204        no     yes    yes      yes       no   high      low   low  low  low
## 50        yes      no    yes      yes       no   high     high  high  low  low
## 145        no     yes    yes      yes       no   high     high  high  low  low
## 176       yes     yes    yes      yes       no   high     high  high high high
## 164        no     yes     no      yes       no   high      low   low  low high
## 352        no     yes    yes      yes       no   high     high  high  low  low
```

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## 225        yes      no    yes      yes       no   high      low   low  low  low
## 258         no     yes    yes      yes       no   high      low   low  low  low
## 117        yes     yes    yes       no       no   high     high   low  low  low
## 88         yes     yes    yes      yes       no   high      low   low  low  low
## 359         no      no    yes      yes      yes    low      low   low  low  low
## 71          no     yes    yes      yes       no   high      low   low  low  low
## 266        yes     yes    yes      yes       no   high      low  high  low high
## 102        yes     yes    yes      yes      yes   high     high   low  low  low
## 302         no     yes    yes      yes       no   high      low   low  low  low
## 19         yes     yes    yes      yes       no   high     high  high  low high
## 47          no     yes    yes      yes       no    low      low  high  low high
## 161        yes     yes     no      yes      yes    low      low   low  low  low
## 66         yes     yes    yes      yes       no   high     high   low  low  low
## 245         no      no    yes      yes      yes   high     high  high  low  low
## 303         no     yes    yes      yes       no   high      low   low  low  low
## 139         no     yes    yes       no      yes   high     high  high  low  low
## 218         no     yes    yes      yes       no    low      low  high  low high
## 362        yes      no     no       no       no   high     high   low  low  low
## 4          yes     yes    yes      yes      yes    low      low   low  low  low
## 16          no     yes    yes      yes       no   high     high  high  low  low
## 326        yes     yes    yes      yes       no   high      low   low  low  low
## 262         no      no    yes      yes       no   high      low   low  low  low
## 309        yes     yes    yes       no      yes   high     high   low  low  low
## 99         yes      no    yes      yes       no   high      low  high  low  low
## 393         no      no    yes       no       no   high     high   low  low  low
## 123        yes     yes    yes      yes      yes   high      low   low  low  low
## 365         no      no    yes       no       no    low      low   low  low  low
## 10         yes     yes    yes      yes       no   high     high   low  low  low
## 28          no     yes    yes      yes       no    low      low  high  low high
## 351         no     yes    yes      yes       no   high     high  high  low  low
## 91          no     yes    yes      yes      yes   high      low   low  low  low
## 114         no     yes    yes      yes       no    low     high   low  low  low
## 265        yes     yes    yes      yes      yes   high      low   low  low  low
## 313         no      no    yes      yes       no   high     high   low  low  low
## 368         no     yes    yes      yes      yes   high      low   low  low  low
## 233        yes     yes    yes      yes      yes   high     high  high  low  low
## 206         no     yes    yes      yes      yes   high     high   low  low high
## 7           no     yes    yes      yes       no   high     high  high  low  low
## 332         no     yes    yes      yes      yes   high     high   low  low  low
## 222        yes     yes    yes       no      yes   high      low  high  low  low
## 109        yes     yes    yes      yes      yes    low      low  high  low high
## 252         no      no    yes      yes       no   high      low   low  low  low
## 348         no     yes    yes      yes      yes   high     high  high  low  low
## 232        yes     yes    yes      yes       no   high     high   low  low  low
## 346         no     yes    yes      yes      yes   high     high   low  low  low
## 55          no     yes    yes      yes       no   high      low  high high high
## 259        yes     yes    yes      yes       no   high      low  high  low  low
## 373        yes     yes    yes       no      yes    low     high   low  low  low
## 193        yes      no    yes      yes       no   high     high  high high high
## 112        yes     yes    yes      yes       no   high      low   low  low  low
## 44          no     yes    yes      yes       no   high     high   low  low  low
## 354         no     yes    yes      yes       no   high     high  high  low  low
## 53          no     yes    yes       no       no   high     high  high  low high
## 13         yes     yes    yes      yes       no   high      low   low  low  low
```

```
## 110        yes     yes    yes      yes      yes   high     high  high  low  low
## 14          no     yes    yes      yes       no   high     high   low  low  low
## 377         no      no    yes      yes      yes   high     high   low  low  low
## 85         yes      no    yes      yes       no   high      low   low  low  low
## 179        yes     yes    yes      yes      yes   high      low   low  low high
## 163        yes     yes    yes       no       no   high     high  high  low high
## 272        yes     yes    yes      yes      yes   high     high  high  low  low
## 205        yes      no    yes      yes       no   high      low  high  low  low
## 113        yes     yes    yes      yes       no    low      low   low  low  low
## 228         no      no    yes      yes       no   high      low   low  low  low
## 170         no     yes    yes      yes      yes   high     high   low  low  low
## 8           no     yes    yes       no       no   high      low  high  low  low
## 327        yes      no    yes      yes       no   high      low  high  low high
## 319        yes      no    yes      yes       no   high      low  high  low high
## 201        yes     yes    yes      yes       no   high      low  high  low high
## 74         yes     yes    yes       no       no   high      low   low  low  low
## 49          no     yes    yes       no       no   high      low   low  low  low
## 151         no     yes     no      yes      yes    low      low  high  low high
## 338         no     yes    yes      yes      yes   high      low   low  low  low
## 253         no      no     no      yes       no    low      low  high  low high
## 35          no      no    yes      yes       no   high     high   low  low  low
## 308         no     yes    yes      yes      yes   high      low  high  low  low
## 321         no     yes    yes      yes      yes   high      low   low  low  low
## 125         no     yes    yes      yes      yes   high     high  high  low  low
## 310        yes      no    yes      yes       no   high     high   low  low  low
## 324         no      no    yes      yes       no    low     high   low  low  low
## 2           no      no    yes      yes       no   high      low   low  low  low
## 100         no     yes    yes      yes       no   high      low  high  low  low
## 372        yes     yes     no      yes      yes   high      low   low  low  low
## 325         no     yes    yes      yes       no    low      low   low  low  low
## 367         no     yes    yes      yes      yes   high      low   low  low  low
## 84         yes     yes    yes      yes       no   high      low   low  low  low
## 90          no     yes    yes       no       no   high      low   low  low high
## 314         no      no    yes      yes      yes   high      low   low  low  low
## 267        yes     yes    yes      yes      yes   high     high  high  low high
## 153        yes     yes    yes      yes      yes   high      low   low  low  low
## 350         no      no    yes      yes       no    low     high  high high high
## 211        yes     yes    yes      yes       no   high      low   low  low  low
## 342        yes     yes    yes      yes       no   high      low   low  low  low
## 217         no     yes    yes      yes      yes    low     high  high  low high
## 370         no      no    yes      yes      yes    low      low   low high  low
## 208        yes     yes    yes      yes      yes    low      low   low  low  low
## 67         yes      no    yes      yes      yes    low      low   low high high
## 162         no     yes    yes      yes      yes   high     high  high  low high
## 255         no      no    yes      yes       no   high     high   low  low high
## 301         no     yes    yes      yes      yes   high      low  high  low  low
## 289        yes     yes    yes      yes       no   high      low  high  low  low
## 52          no     yes    yes      yes       no   high      low   low  low  low
## 45         yes     yes    yes      yes       no   high      low   low  low  low
## 333        yes     yes    yes      yes       no   high      low  high  low  low
## 345         no     yes    yes      yes       no   high      low   low  low  low
## 316         no     yes    yes      yes      yes   high      low   low  low  low
## 277         no      no     no      yes      yes   high      low   low  low  low
## 189         no      no    yes      yes      yes    low      low   low  low  low
```

```
## 63         yes     yes    yes      yes       no   high     high   low  low  low
## 142        yes     yes    yes      yes       no    low      low   low  low  low
## 106         no     yes    yes       no       no   high      low   low  low  low
## 384         no     yes    yes       no       no   high      low   low  low  low
## 122        yes     yes    yes      yes       no   high     high  high  low  low
## 263        yes      no    yes       no       no   high      low   low  low  low
## 297        yes     yes    yes      yes       no    low      low  high  low  low
## 306        yes     yes    yes      yes       no   high     high   low  low  low
## 87          no     yes    yes       no       no   high      low  high  low  low
## 121         no      no    yes      yes       no    low      low   low  low  low
## 6          yes     yes    yes      yes       no   high     high   low  low  low
## 293         no     yes    yes      yes      yes   high     high   low  low  low
## 356         no     yes    yes       no      yes   high      low  high  low  low
## 81         yes      no    yes      yes      yes    low      low   low  low  low
## 246         no     yes    yes      yes       no   high      low   low  low  low
## 209         no     yes    yes       no       no   high      low   low  low high
## 39         yes     yes    yes      yes       no   high      low   low  low  low
## 147         no     yes    yes      yes       no    low      low   low  low  low
## 219         no     yes    yes       no       no    low      low   low  low high
## 169         no      no    yes      yes       no   high      low  high  low  low
## 268        yes     yes    yes      yes       no   high      low  high  low  low
## 278        yes     yes    yes      yes       no    low      low  high  low high
## 210        yes     yes    yes      yes      yes   high     high   low  low  low
## 124        yes     yes    yes      yes       no    low     high  high  low high
## 20         yes     yes    yes      yes       no    low      low   low  low  low
## 5           no     yes    yes       no       no   high      low   low  low  low
## 203         no      no    yes       no       no   high     high  high  low  low
## 236        yes     yes    yes      yes      yes   high      low   low  low  low
## 135         no     yes    yes       no      yes   high      low   low  low  low
## 177        yes      no    yes      yes       no    low     high  high  low high
## 69          no     yes    yes      yes       no   high      low   low  low  low
## 291        yes     yes    yes      yes      yes   high      low   low  low high
## 380        yes      no    yes      yes       no   high     high  high  low  low
## 299         no     yes    yes      yes       no   high      low   low  low  low
## 311        yes      no    yes       no      yes   high      low  high  low  low
## 202        yes     yes    yes       no       no   high     high   low  low  low
## 146         no     yes    yes      yes       no   high     high   low  low  low
## 223         no     yes    yes      yes       no    low      low   low  low  low
## 390        yes     yes    yes       no       no    low      low   low  low  low
## 181        yes     yes    yes      yes       no    low     high   low  low  low
## 312         no     yes     no      yes      yes    low     high   low  low  low
## 242         no     yes    yes      yes       no    low      low   low  low  low
## 158        yes      no    yes       no       no   high      low  high  low high
## 382        yes      no    yes      yes      yes   high     high   low  low  low
## 42          no      no    yes      yes      yes   high     high   low  low high
## 24         yes     yes    yes      yes       no   high     high  high  low high
## 173        yes     yes    yes      yes       no   high     high  high  low  low
## 294         no     yes    yes       no       no    low      low   low  low  low
## 159         no      no    yes       no       no   high      low   low  low  low
## 323        yes     yes    yes      yes       no    low      low   low  low  low
## 129        yes     yes    yes      yes       no    low      low   low  low  low
## 290        yes     yes    yes      yes       no   high     high   low  low  low
## 79         yes     yes     no      yes       no   high     high   low  low  low
## 286         no      no    yes      yes       no   high      low   low  low  low
```

```
## 331        yes     yes    yes      yes       no   high     high  high  low high
## 144         no     yes    yes      yes       no    low     high  high  low  low
## 41         yes      no    yes      yes      yes    low      low   low  low  low
## 118        yes     yes    yes      yes       no   high     high   low  low  low
## 51          no     yes    yes      yes       no   high      low   low  low  low
## 344         no     yes    yes      yes      yes    low      low   low  low  low
## 361         no     yes    yes       no      yes   high      low  high  low high
## 349        yes     yes    yes      yes      yes   high     high   low  low  low
## 387        yes     yes    yes      yes      yes   high     high   low  low  low
## 83          no     yes    yes      yes       no   high     high  high  low  low
## 381        yes      no    yes      yes       no    low      low  high  low high
## 375         no     yes    yes      yes       no   high     high  high  low  low
## 64         yes     yes    yes      yes       no    low     high  high  low high
## 280        yes     yes    yes      yes       no   high      low   low  low  low
## 270         no     yes     no      yes      yes   high      low  high  low  low
## 23         yes     yes    yes      yes       no   high     high   low  low  low
## 27          no     yes    yes      yes       no   high      low   low  low  low
## 230        yes     yes    yes      yes      yes    low      low   low  low  low
## 172        yes     yes    yes      yes      yes   high      low   low  low  low
## 26          no      no    yes      yes       no    low      low   low  low  low
## 251         no     yes     no      yes       no   high     high  high  low high
## 86          no     yes    yes      yes      yes   high     high  high  low  low
## 184        yes     yes    yes      yes      yes   high      low   low  low  low
## 360         no     yes    yes      yes       no   high      low   low  low  low
## 335        yes     yes    yes       no       no   high     high  high  low  low
## 307        yes     yes    yes       no       no   high     high   low  low  low
## 248         no      no     no      yes      yes   high     high  high high high
## 357        yes     yes    yes      yes       no   high      low   low  low  low
## 339         no     yes    yes      yes       no   high      low   low  low  low
## 132        yes      no    yes      yes      yes   high      low   low  low  low
## 111        yes     yes    yes      yes       no   high     high   low  low  low
## 199         no     yes    yes      yes       no   high      low  high  low  low
## 207         no     yes    yes      yes       no    low      low   low  low  low
## 141         no     yes    yes      yes       no    low      low   low  low  low
## 298         no     yes    yes      yes      yes   high     high  high  low  low
## 77         yes     yes    yes      yes       no    low     high   low  low  low
## 355        yes      no    yes      yes      yes   high     high  high  low  low
## 257        yes     yes    yes      yes       no   high      low   low  low  low
## 318        yes     yes    yes      yes      yes   high      low  high  low  low
## 38         yes     yes    yes      yes      yes    low     high   low  low  low
## 216         no     yes    yes      yes       no   high     high  high  low  low
## 92         yes     yes    yes      yes       no   high     high  high  low  low
## 379         no     yes    yes      yes      yes   high      low   low  low  low
## 190         no     yes    yes       no       no    low      low   low low high
## 305        yes     yes    yes      yes      yes   high     high  high  low  low
## 103        yes      no    yes      yes       no   high      low   low  low  low
## 320         no     yes    yes      yes       no   high     high  high  low  low
## 57         yes     yes    yes      yes       no   high      low   low  low  low
## 353         no     yes     no      yes      yes   high      low   low  low  low
## 61         yes     yes    yes       no       no    low     high  high  low  low
## 134         no     yes    yes      yes       no    low      low   low low high
## 220        yes     yes    yes      yes       no   high      low   low  low  low
## 287         no     yes    yes      yes       no   high      low   low  low  low
## 167         no     yes     no      yes       no   high      low  high  low high
```

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## 1           no     yes    yes       no       no   high      low  high  low  low
## 215         no     yes    yes       no       no   high      low   low  low  low
## 3           no     yes    yes      yes       no   high      low   low  low  low
## 30         yes     yes    yes      yes      yes   high     high  high high high
## 82          no      no    yes      yes       no   high      low   low  low  low
## 143        yes     yes    yes      yes       no   high      low   low  low  low
## 93          no     yes    yes       no       no    low      low   low  low  low
## 337         no     yes    yes       no       no   high     high   low  low  low
## 221        yes     yes    yes      yes       no   high      low  high  low  low
## 364        yes     yes    yes      yes      yes    low      low  high  low  low
## 96         yes     yes    yes      yes       no    low      low   low  low  low
## 126         no     yes    yes      yes       no   high     high  high  low  low
## 214        yes     yes    yes      yes       no   high     high  high  low high
## 188        yes     yes    yes      yes      yes   high      low   low  low  low
## 285         no      no    yes      yes       no   high     high  high  low  low
## 371        yes     yes    yes       no      yes    low      low   low  low  low
## 271        yes     yes    yes      yes       no   high      low  high  low  low
## 295        yes     yes    yes      yes       no   high     high   low  low  low
## 157         no     yes    yes       no       no    low      low   low  low  low
## 25         yes     yes    yes      yes       no   high      low   low  low  low
## 212         no     yes    yes      yes      yes   high      low  high high high
## 238         no     yes    yes      yes      yes   high     high   low  low  low
## 156        yes     yes    yes       no       no   high     high  high  low  low
## 213         no     yes    yes      yes       no    low      low  high  low  low
## 148         no      no    yes      yes       no   high      low   low  low  low
## 234        yes     yes    yes      yes       no   high      low  high  low high
## 56         yes     yes    yes      yes      yes   high      low  high  low  low
## 107         no     yes    yes      yes       no   high      low   low  low  low
## 154         no     yes     no      yes      yes   high     high  high  low  low
## 191         no     yes    yes      yes       no   high      low   low  low  low
## 249         no     yes    yes      yes      yes   high      low   low  low  low
## 366         no     yes    yes       no       no    low      low  high  low high
## 54          no     yes    yes      yes       no    low      low  high  low  low
##     health absences G1 G2 G3 first_gen_college stable_learning_env
## 261    low       21 17 18 18                no                 yes
## 186   high       12 12 12 11               yes                 yes
## 140   high        0 16 16 15                no                  no
## 36    high        0  8  7  6               yes                  no
## 394   high        0 11 12 10               yes                  no
## 363    low        0 11 11 10               yes                 yes
## 276   high        6 12 12 12               yes                 yes
## 330   high        4 14 14 14                no                 yes
## 183   high        0 16 17 17                no                  no
## 168    low        0 14 15 16                no                  no
## 48     low        4 19 19 20                no                  no
## 104    low       26  7  6  6               yes                 yes
## 136   high        0 11  0  0                no                 yes
## 37    high        2 15 16 18                no                 yes
## 108   high        2 16 18 18               yes                 yes
## 395   high        5  8  9  9               yes                  no
## 165   high        0  5  8  7               yes                  no
## 137   high        0 10  0  0                no                  no
## 256   high        2  7  9  8               yes                 yes
## 376   high        2  8  8 10               yes                  no
```

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## 374    low       14  6  5  5              yes                 no
## 274    low        2 15 14 14              yes                 no
## 12    high        4 10 12 12              yes                yes
## 40     low        8 14 13 13              yes                 no
## 22    high        0 12 15 15               no                yes
## 70     low       12 16 16 16              yes                yes
## 296   high        4 14 12 11              yes                yes
## 15     low        0 14 16 16              yes                yes
## 388   high        0  7  5  0              yes                 no
## 75    high       54 11 12 11              yes                yes
## 29    high        4 11 11 11               no                yes
## 343   high       11 16 15 15               no                 no
## 131   high        0 12  0  0               no                yes
## 62    high        6 10  8 11              yes                yes
## 127    low        0  7 10 11               no                 no
## 101   high       14  7  7  5               no                yes
## 247    low        4 12 12 13              yes                 no
## 182    low        2 12 13 12              yes                 no
## 383    low        2 11 11 10              yes                 no
## 138   high        0  4  0  0              yes                yes
## 68    high        4  7  7  6              yes                yes
## 33    high        0 17 16 16               no                yes
## 275    low        2 10 10 10               no                yes
## 166    low       16 12 11 12              yes                 no
## 185    low       14 12 13 12              yes                yes
## 237   high        4 14 13 13              yes                 no
## 192    low        0  8  8  9              yes                 no
## 391   high       11  9  9  9              yes                 no
## 65     low        0 10 10 10               no                 no
## 9      low        0 16 18 19              yes                yes
## 241   high       14 12 12 12               no                 no
## 105    low        0 16 18 18               no                yes
## 197   high        4 17 15 16               no                 no
## 128   high        2  7  8  9              yes                 no
## 198    low        8  9  9 10              yes                yes
## 317    low        0  8  8  0              yes                yes
## 171    low        0  6  5  0               no                yes
## 392    low        3 14 16 16              yes                 no
## 334    low        0  8  8  0              yes                 no
## 73    high        2  8  6  5              yes                yes
## 195    low        0 13 14 14              yes                 no
## 204    low       18  7  6  6              yes                yes
## 50     low        2  7  7  7               no                yes
## 145   high        0  5  0  0              yes                yes
## 176   high        4 10  9  9               no                 no
## 164    low        2 10 10 10              yes                 no
## 352    low        2 13 13 13              yes                yes
## 225   high        0 13 13 14               no                yes
## 258    low       12 11 11 11               no                yes
## 117    low        2 11 13 14               no                 no
## 88     low        4 13 14 14               no                yes
## 359    low        4 10 10 10              yes                 no
## 71    high        0 13 15 15              yes                yes
## 266    low       13 17 17 17               no                yes
```

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## 102   high        0 16 17 17              no               yes
## 302   high        0 11 11 10              no                no
## 19    high       16  6  5  5             yes               yes
## 47     low       12 11 12 11             yes               yes
## 161   high        0  7  6  0             yes                no
## 66     low        2 16 15 15              no               yes
## 245    low        0  7  0  0             yes               yes
## 303    low        0 15 12 14              no               yes
## 139   high        0 14 12 12             yes                no
## 218   high       13  6  6  8             yes               yes
## 362   high        2 13 12 12             yes                no
## 4     high        2 15 14 15              no               yes
## 16     low        4 14 14 14              no               yes
## 326    low        3  9 12 11              no                no
## 262    low        2  8  8  8              no               yes
## 309   high        0 15 12 12             yes                no
## 99     low        6 11 14 14              no                no
## 393    low        3 10  8  7             yes                no
## 123   high        2 13 13 13              no               yes
## 365    low        0 12 11 12             yes                no
## 10    high        0 14 15 15              no               yes
## 28     low        4 15 16 15              no                no
## 351    low        8  8  7  8             yes                no
## 91    high        0  7  7  8             yes               yes
## 114    low       10 18 19 19              no                no
## 265    low        0  9 10  0             yes               yes
## 313   high        3 13 11 11             yes                no
## 368    low        0  7  6  0             yes               yes
## 233    low       14 11  9  9              no               yes
## 206   high       28 10  9  9              no               yes
## 7      low        0 12 12 11             yes                no
## 332   high        7 12 14 14              no               yes
## 222   high        0  6  5  0             yes                no
## 109    low        6 10 13 13              no               yes
## 252    low        6  7 10 10             yes               yes
## 348   high        0 10 10  9              no               yes
## 232    low        4 11 11 11             yes               yes
## 346    low        7 13 13 14             yes                no
## 55     low        6 10 13 13             yes                no
## 259   high        8 15 14 14             yes                no
## 373    low        8 13 11 11             yes                no
## 193   high       12  7  8  8             yes                no
## 112    low        0  7 10 10             yes               yes
## 44     low        0  8  8 11             yes               yes
## 354   high        4  8  8  8             yes               yes
## 53    high        6 11 11 10              no                no
## 13    high        2 14 14 14              no               yes
## 110   high        4 14 15 16              no               yes
## 14     low        2 10 10 11              no               yes
## 377    low        4 15 14 15              no               yes
## 85    high        2  9 10 10             yes               yes
## 179    low       10 10  8  9              no               yes
## 163   high        0  7  0  0             yes                no
## 272    low        4 15 14 14             yes               yes
```

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## 205   high        6 10 10 11              yes               yes
## 113   high        6 10 13 13              yes                no
## 228    low        2 12 11 12              yes               yes
## 170    low        0 14 14 14               no               yes
## 8      low        6  6  5  6               no                no
## 327   high        3 14 15 16              yes                no
## 319   high        0 11 11 10               no               yes
## 201    low        2 16 16 16               no               yes
## 74    high        2 12 12 14              yes                no
## 49    high        2 15 15 14               no                no
## 151   high        0  6  5  0              yes                no
## 338    low        0  7  8  0              yes               yes
## 253   high        4  6  9  8              yes                no
## 35    high        0 12 14 15              yes               yes
## 308   high       38  8  9  8               no               yes
## 321   high       23 13 13 13               no               yes
## 125   high        0  8  7  8              yes                no
## 310    low       18 12 10 10              yes               yes
## 324   high        1 12 14 15              yes               yes
## 2      low        4  5  5  6              yes               yes
## 100    low        0  7  9  8               no               yes
## 372    low        3 14 12 12              yes               yes
## 325    low        0 16 15 15              yes                no
## 367   high        0 13 13 13               no                no
## 84    high        4 15 15 15              yes                no
## 90    high       18  8  6  7               no                no
## 314    low       22 13 10 11              yes               yes
## 267   high        2  9  9 10              yes                no
## 153    low        8 10 10 10              yes               yes
## 350   high       10 11 13 13              yes               yes
## 211    low       10  8  8  8              yes               yes
## 342    low        0 10 10  0               no               yes
## 217    low       22  6  6  4               no                no
## 370   high       10 14 12 11               no               yes
## 208    low       10 11 12 13               no                no
## 67     low        4 13 13 12               no               yes
## 162    low        6  5  9  7              yes               yes
## 255   high        0  8 12 12              yes                no
## 301   high       14 12 10 11               no               yes
## 289    low        6 15 14 14              yes                no
## 52    high        2 11 13 13               no               yes
## 45    high       14 10 10  9              yes                no
## 333   high        0  7  0  0              yes                no
## 345    low        4 11 10 10              yes               yes
## 316    low       40 13 11 11              yes                no
## 277   high       75 10  9  9              yes                no
## 189    low        6  8  7  9              yes               yes
## 63     low        4  8 10  9              yes                no
## 142    low        8  9  9  9              yes               yes
## 106   high       10 10 11 11              yes                no
## 384   high        0  6  5  0              yes                no
## 122   high        6 16 14 15              yes               yes
## 263    low        1 13 12 12              yes                no
## 297    low        0 10  9  0               no               yes
```

```
## 306    low        8 14 12 12              no              yes
## 87     low        4  8  7  6             yes               no
## 121    low        2 16 15 15             yes               no
## 6     high       10 15 15 15              no              yes
## 293   high       12 12 12 13             yes               no
## 356   high        0 10  9  9             yes               no
## 81     low        2 10 12 12             yes              yes
## 246   high        6 18 18 18             yes               no
## 209   high        6  9  9 10             yes               no
## 39    high        2 12 12 11              no              yes
## 147    low        0  6  7  0             yes              yes
## 219    low        3  7  7  8             yes               no
## 169   high        0  6  7  0             yes              yes
## 268   high        8 12 10 11              no               no
## 278    low       22  9  9  9              no               no
## 210   high        6  7  7  7              no              yes
## 124   high       18 14 11 13              no              yes
## 20    high        4  8 10 10              no               no
## 5     high        4  6 10 10             yes               no
## 203    low        4  9  9 10             yes               no
## 236    low       10 11  9 10             yes               no
## 135   high        0  9  0  0              no               no
## 177   high        2 13 13 11             yes               no
## 69    high        2  8  9  8             yes              yes
## 291   high       11 12 11 11              no              yes
## 380    low       17 10 10 10             yes              yes
## 299    low        0 14 13 14              no              yes
## 311    low        0  9  9  0             yes               no
## 202   high        6  8 10 10             yes               no
## 146   high        0  8 11 11             yes              yes
## 223    low        2 16 16 17             yes               no
## 390   high        0  6  5  0             yes               no
## 181    low       10  9  8  8              no              yes
## 312    low       20 14 12 13             yes              yes
## 242   high        2 10 11 12              no              yes
## 158   high        6  9  8 10             yes               no
## 382   high        5  7  6  7             yes               no
## 42    high        8 12 12 12              no              yes
## 24    high        0 13 13 12             yes              yes
## 173   high        0 13 11 10              no              yes
## 294    low        6 18 18 18             yes               no
## 159    low        2 17 15 15             yes               no
## 323    low        3 11 11 11             yes              yes
## 129   high        0  7  4  0             yes              yes
## 290    low        9 15 13 15              no              yes
## 79     low        2  8  8 10             yes              yes
## 286   high        2 12 10 11             yes               no
## 331   high        2  9  8  8             yes              yes
## 144    low        2 14 14 13             yes               no
## 41     low       25  7 10 11             yes              yes
## 118   high        0 13 14 13             yes               no
## 51    high        2 12 13 13             yes              yes
## 344   high        0  9  8  0             yes              yes
## 361   high        0 13 13 13              no               no
```

```
## 349   high        0 13 15 15              no               yes
## 387   high        7  6  5  6              no               yes
## 83    high       10  7  6  6             yes               yes
## 381    low        4 15 14 14              no                no
## 375    low        0 19 18 19              no                no
## 64    high        2 10  9  9              no               yes
## 280    low        8 10 11 10              no                no
## 270    low        0  6  0  0             yes               yes
## 23    high        2 15 15 16              no                no
## 27    high        2 12 12 11             yes               yes
## 230    low       10 12 10 12             yes                no
## 172    low        2 13 15 16             yes               yes
## 26    high       14  6  9  8             yes               yes
## 251   high        0  6  8  8             yes                no
## 86    high        6  7  9  8              no                no
## 184    low       56  9  9  8             yes               yes
## 360   high        0 18 16 16             yes                no
## 335   high        0 10  9  0             yes                no
## 307   high        0 17 18 18             yes                no
## 248    low       16  6  8  8             yes                no
## 357   high        4 12 13 13              no               yes
## 339    low        7 16 15 17             yes               yes
## 132   high        0  8  0  0             yes               yes
## 111   high        6 18 19 19              no                no
## 199    low       24 18 18 18              no               yes
## 207   high        5  7  7  7             yes               yes
## 141    low        0  7  9  0              no               yes
## 298    low       10 10  8  8              no               yes
## 77     low        8 11 11 10              no                no
## 355    low        4 13 11 11              no               yes
## 257   high        6 14 12 13              no               yes
## 318   high        9  9 10  9              no               yes
## 38    high        7 15 16 15              no               yes
## 216    low        2 14 15 15             yes                no
## 92     low        4 16 17 18              no                no
## 379    low        0 15 15 15             yes                no
## 190    low        4  8  9 10             yes                no
## 305    low       20 15 14 13             yes               yes
## 103   high        4 10 13 14              no               yes
## 320   high        2 11 11 11              no               yes
## 57     low        0 14 15 15              no               yes
## 353    low        7  8  7  8             yes                no
## 61    high        6 10 11 11              no                no
## 134   high       16 12 11 11              no                no
## 220   high        4  9 10 10             yes               yes
## 287    low        5 18 18 19             yes               yes
## 167   high        4 10 10 10             yes                no
## 1      low        6  5  6  6              no                no
## 215    low       12  8 10 10              no                no
## 3      low       10  7  8 10             yes                no
## 30    high       16 10 12 11              no               yes
## 82    high        4 11 10 11             yes                no
## 143   high        2  9 11 11              no               yes
## 93     low        4  7  6  6             yes                no
```

```
## 337   high       12 14 13 13              yes                  no
## 221   high        2  6  6  6              yes                 yes
## 364    low        0 16 15 15               no                 yes
## 96     low        2  7 10 10              yes                 yes
## 126   high        0 13 13 12               no                  no
## 214   high       15  6  7  8              yes                 yes
## 188   high        0 15 15 15              yes                  no
## 285   high        4 10  9 11              yes                 yes
## 371    low        4  7  7  9              yes                  no
## 271   high       15  9  9  9              yes                 yes
## 295   high        8 14 13 14              yes                 yes
## 157   high        8 16 12 13              yes                  no
## 25    high        2 10  9  8               no                 yes
## 212    low       13 12 12 13               no                 yes
## 238   high       20 13 12 12              yes                  no
## 156    low        2 11  8  8              yes                  no
## 213   high        0 12 13 14              yes                 yes
## 148   high        2 10 11 11              yes                 yes
## 234    low        2 14 13 13               no                 yes
## 56     low        8  8  9 10              yes                  no
## 107    low        8  7  8  8              yes                 yes
## 154   high        0  5  0  0              yes                 yes
## 191    low       10 11 12 13              yes                  no
## 249   high        8  3  5  5              yes                 yes
## 366    low        4 10 10 10              yes                  no
## 54    high        0  8 10 11               no                 yes
##     high_freq_absent failed ord_g3
## 261              yes     no     18
## 186              yes     no     11
## 140               no     no     15
## 36                no     no      6
## 394               no     no     10
## 363               no     no     10
## 276               no     no     12
## 330               no     no     14
## 183               no     no     17
## 168               no     no     16
## 48                no     no     20
## 104              yes     no      6
## 136               no     no      0
## 37                no     no     18
## 108               no     no     18
## 395               no     no      9
## 165               no    yes      7
## 137               no     no      0
## 256               no    yes      8
## 376               no     no     10
## 374              yes     no      5
## 274               no     no     14
## 12                no     no     12
## 40                no     no     13
## 22                no     no     15
## 70               yes     no     16
## 296               no     no     11
```

```
## 15               no     no     16
## 388              no    yes      0
## 75              yes     no     11
## 29               no     no     11
## 343             yes     no     15
## 131              no    yes      0
## 62               no     no     11
## 127              no     no     11
## 101             yes     no      5
## 247              no     no     13
## 182              no     no     12
## 383              no     no     10
## 138              no    yes      0
## 68               no     no      6
## 33               no     no     16
## 275              no     no     10
## 166             yes    yes     12
## 185             yes     no     12
## 237              no     no     13
## 192              no     no      9
## 391             yes    yes      9
## 65               no     no     10
## 9                no     no     19
## 241             yes     no     12
## 105              no     no     18
## 197              no     no     16
## 128              no    yes      9
## 198              no     no     10
## 317              no     no      0
## 171              no    yes      0
## 392              no     no     16
## 334              no     no      0
## 73               no    yes      5
## 195              no     no     14
## 204             yes     no      6
## 50               no    yes      7
## 145              no    yes      0
## 176              no     no      9
## 164              no     no     10
## 352              no     no     13
## 225              no     no     14
## 258             yes     no     11
## 117              no     no     14
## 88               no     no     14
## 359              no     no     10
## 71               no     no     15
## 266             yes     no     17
## 102              no     no     17
## 302              no     no     10
## 19              yes    yes      5
## 47              yes     no     11
## 161              no    yes      0
## 66               no     no     15
## 245              no     no      0
```

```
## 303              no     no     14
## 139              no    yes     12
## 218             yes    yes      8
## 362              no    yes     12
## 4                no     no     15
## 16               no     no     14
## 326              no     no     11
## 262              no     no      8
## 309              no    yes     12
## 99               no     no     14
## 393              no    yes      7
## 123              no     no     13
## 365              no     no     12
## 10               no     no     15
## 28               no     no     15
## 351              no    yes      8
## 91               no     no      8
## 114             yes     no     19
## 265              no     no      0
## 313              no    yes     11
## 368              no    yes      0
## 233             yes     no      9
## 206             yes    yes      9
## 7                no     no     11
## 332              no     no     14
## 222              no    yes      0
## 109              no     no     13
## 252              no     no     10
## 348              no     no      9
## 232              no     no     11
## 346              no     no     14
## 55               no     no     13
## 259              no     no     14
## 373              no     no     11
## 193             yes     no      8
## 112              no    yes     10
## 44               no     no     11
## 354              no    yes      8
## 53               no    yes     10
## 13               no     no     14
## 110              no     no     16
## 14               no     no     11
## 377              no    yes     15
## 85               no     no     10
## 179             yes     no      9
## 163              no    yes      0
## 272              no     no     14
## 205              no     no     11
## 113              no    yes     13
## 228              no     no     12
## 170              no     no     14
## 8                no     no      6
## 327              no     no     16
## 319              no     no     10
```

```
## 201              no     no     16
## 74               no     no     14
## 49               no     no     14
## 151              no    yes      0
## 338              no     no      0
## 253              no    yes      8
## 35               no     no     15
## 308             yes    yes      8
## 321             yes     no     13
## 125              no     no      8
## 310             yes    yes     10
## 324              no     no     15
## 2                no     no      6
## 100              no     no      8
## 372              no     no     12
## 325              no     no     15
## 367              no     no     13
## 84               no     no     15
## 90              yes     no      7
## 314             yes    yes     11
## 267              no     no     10
## 153              no    yes     10
## 350             yes    yes     13
## 211             yes     no      8
## 342              no    yes      0
## 217             yes    yes      4
## 370             yes     no     11
## 208             yes     no     13
## 67               no     no     12
## 162              no    yes      7
## 255              no     no     12
## 301             yes     no     11
## 289              no     no     14
## 52               no     no     13
## 45              yes    yes      9
## 333              no     no      0
## 345              no     no     10
## 316             yes    yes     11
## 277             yes     no      9
## 189              no     no      9
## 63               no     no      9
## 142              no    yes      9
## 106             yes     no     11
## 384              no    yes      0
## 122              no     no     15
## 263              no     no     12
## 297              no     no      0
## 306              no    yes     12
## 87               no     no      6
## 121              no     no     15
## 6               yes     no     15
## 293             yes    yes     13
## 356              no     no      9
## 81               no     no     12
```

```
## 246              no     no     18
## 209              no     no     10
## 39               no     no     11
## 147              no    yes      0
## 219              no     no      8
## 169              no     no      0
## 268              no     no     11
## 278             yes     no      9
## 210              no     no      7
## 124             yes     no     13
## 20               no     no     10
## 5                no     no     10
## 203              no     no     10
## 236             yes     no     10
## 135              no     no      0
## 177              no     no     11
## 69               no     no      8
## 291             yes     no     11
## 380             yes     no     10
## 299              no     no     14
## 311              no    yes      0
## 202              no     no     10
## 146              no     no     11
## 223              no     no     17
## 390              no    yes      0
## 181             yes     no      8
## 312             yes     no     13
## 242              no     no     12
## 158              no    yes     10
## 382              no     no      7
## 42               no     no     12
## 24               no     no     12
## 173              no     no     10
## 294              no     no     18
## 159              no     no     15
## 323              no     no     11
## 129              no    yes      0
## 290              no     no     15
## 79               no    yes     10
## 286              no     no     11
## 331              no     no      8
## 144              no     no     13
## 41              yes    yes     11
## 118              no     no     13
## 51               no     no     13
## 344              no    yes      0
## 361              no     no     13
## 349              no     no     15
## 387              no     no      6
## 83              yes     no      6
## 381              no     no     14
## 375              no     no     19
## 64               no     no      9
## 280              no     no     10
```

```
## 270              no     no      0
## 23               no     no     16
## 27               no     no     11
## 230             yes     no     12
## 172              no     no     16
## 26              yes    yes      8
## 251              no    yes      8
## 86               no    yes      8
## 184             yes     no      8
## 360              no     no     16
## 335              no     no      0
## 307              no     no     18
## 248             yes    yes      8
## 357              no     no     13
## 339              no     no     17
## 132              no     no      0
## 111              no     no     19
## 199             yes    yes     18
## 207              no    yes      7
## 141              no     no      0
## 298             yes     no      8
## 77               no     no     10
## 355              no     no     11
## 257              no     no     13
## 318              no     no      9
## 38               no     no     15
## 216              no     no     15
## 92               no     no     18
## 379              no     no     15
## 190              no     no     10
## 305             yes    yes     13
## 103              no     no     14
## 320              no     no     11
## 57               no     no     15
## 353              no    yes      8
## 61               no     no     11
## 134             yes     no     11
## 220              no     no     10
## 287              no     no     19
## 167              no     no     10
## 1                no     no      6
## 215             yes     no     10
## 3               yes    yes     10
## 30              yes     no     11
## 82               no     no     11
## 143              no     no     11
## 93               no     no      6
## 337             yes    yes     13
## 221              no     no      6
## 364              no     no     15
## 96               no    yes     10
## 126              no     no     12
## 214             yes    yes      8
## 188              no     no     15
```

```
## 285               no     no     11
## 371               no    yes      9
## 271              yes    yes      9
## 295               no     no     14
## 157               no     no     13
## 25                no     no      8
## 212              yes     no     13
## 238              yes     no     12
## 156               no     no      8
## 213               no     no     14
## 148               no     no     11
## 234               no     no     13
## 56                no     no     10
## 107               no     no      8
## 154               no    yes      0
## 191              yes     no     13
## 249               no    yes      5
## 366               no     no     10
## 54                no     no     11
```

```
testing
```

```
##     school sex age address famsize Pstatus Medu Fedu     Mjob     Fjob
## 11      GP   F  15       U     GT3       T    4    4  teacher   health
## 17      GP   F  16       U     GT3       T    4    4 services services
## 18      GP   F  16       U     GT3       T    3    3    other    other
## 21      GP   M  15       U     GT3       T    4    3  teacher    other
## 31      GP   M  15       U     GT3       T    4    4   health services
## 32      GP   M  15       U     GT3       T    4    4 services services
## 34      GP   M  15       U     LE3       T    3    3    other    other
## 43      GP   M  15       U     GT3       T    4    4 services  teacher
## 46      GP   F  15       U     LE3       A    4    3    other    other
## 58      GP   M  15       U     GT3       T    4    4  teacher   health
## 59      GP   M  15       U     LE3       T    1    2    other  at_home
## 60      GP   F  16       U     GT3       T    4    2 services    other
## 72      GP   M  15       U     GT3       T    4    2    other    other
## 76      GP   M  15       U     GT3       T    4    3  teacher    other
## 78      GP   F  16       U     GT3       T    2    2    other    other
## 80      GP   F  16       U     GT3       T    3    4  at_home    other
## 89      GP   M  16       U     GT3       T    2    2 services    other
## 94      GP   F  16       U     GT3       T    4    2  teacher services
## 95      GP   M  15       U     LE3       T    2    2 services   health
## 97      GP   M  16       R     GT3       T    4    3 services    other
## 98      GP   F  16       U     GT3       T    2    1    other    other
## 115     GP   M  15       R     GT3       T    2    1   health services
## 116     GP   M  16       U     GT3       T    4    4  teacher  teacher
## 119     GP   M  17       R     GT3       T    1    3    other    other
## 120     GP   M  15       U     GT3       T    3    4    other    other
## 130     GP   M  16       R     GT3       T    4    4  teacher  teacher
## 133     GP   F  17       U     LE3       T    2    2    other    other
## 149     GP   M  16       U     GT3       T    4    4  teacher  teacher
## 150     GP   M  15       U     LE3       A    2    1 services    other
## 152     GP   M  16       U     LE3       T    2    1  at_home    other
## 155     GP   F  17       U     GT3       T    4    4    other  teacher
## 160     GP   M  16       U     GT3       T    3    3    other services
```

```
## 174     GP   F  16       U     GT3       T    1    3  at_home services
## 175     GP   F  16       U     LE3       T    3    3    other    other
## 178     GP   M  17       U     GT3       T    3    3    other    other
## 180     GP   M  17       U     GT3       T    4    3    other    other
## 187     GP   M  16       U     GT3       T    1    2 services services
## 194     GP   M  16       R     GT3       T    3    3 services services
## 196     GP   F  17       U     LE3       T    2    4 services services
## 200     GP   F  16       U     LE3       T    4    4  teacher  teacher
## 224     GP   M  18       U     GT3       T    2    2    other    other
## 226     GP   F  18       R     GT3       T    3    1    other    other
## 227     GP   F  17       U     GT3       T    3    2    other    other
## 229     GP   M  18       U     LE3       T    2    1  at_home    other
## 231     GP   F  17       U     LE3       T    4    3   health    other
## 235     GP   M  16       U     LE3       T    1    1    other    other
## 239     GP   F  17       R     GT3       T    2    1  at_home services
## 240     GP   M  18       U     GT3       T    2    2    other services
## 243     GP   M  16       U     LE3       T    4    3  teacher    other
## 244     GP   M  16       U     GT3       T    4    4 services services
## 250     GP   M  16       U     GT3       T    0    2    other    other
## 254     GP   M  16       R     GT3       T    2    1    other    other
## 260     GP   F  17       U     LE3       T    2    2 services services
## 264     GP   F  17       U     GT3       T    3    3    other    other
## 269     GP   M  18       U     GT3       T    4    2   health    other
## 273     GP   F  18       U     LE3       T    1    1    other    other
## 279     GP   F  18       U     GT3       T    4    4   health   health
## 281     GP   M  17       U     LE3       A    4    1 services    other
## 282     GP   M  17       U     LE3       A    3    2  teacher services
## 283     GP   F  18       R     LE3       T    1    1  at_home    other
## 284     GP   F  18       U     GT3       T    1    1    other    other
## 288     GP   F  17       U     GT3       T    1    1 services  teacher
## 292     GP   F  17       U     GT3       T    4    3   health services
## 300     GP   M  18       U     LE3       T    4    4  teacher  teacher
## 304     GP   F  17       U     GT3       T    3    2   health   health
## 315     GP   F  19       U     GT3       T    1    1  at_home   health
## 322     GP   F  17       U     GT3       T    2    2    other    other
## 328     GP   M  17       R     GT3       T    2    2 services    other
## 329     GP   F  17       U     GT3       T    4    4  teacher services
## 336     GP   F  17       U     GT3       T    3    4 services    other
## 340     GP   F  17       R     GT3       A    3    2    other    other
## 341     GP   F  19       U     GT3       T    2    1 services services
## 347     GP   M  18       R     GT3       T    4    3  teacher services
## 358     MS   F  17       U     LE3       A    3    2 services    other
## 369     MS   F  18       U     GT3       T    2    3  at_home services
## 378     MS   F  18       R     LE3       T    4    4  teacher services
## 385     MS   M  18       R     GT3       T    4    2    other    other
## 386     MS   F  18       R     GT3       T    2    2  at_home    other
## 389     MS   F  18       U     LE3       T    3    1  teacher services
##         reason guardian traveltime studytime failures schoolsup famsup paid
## 11  reputation   mother          1         2        0        no    yes  yes
## 17  reputation   mother          1         3        0        no    yes  yes
## 18  reputation   mother          3         2        0       yes    yes   no
## 21  reputation   mother          1         2        0        no     no   no
## 31        home   mother          1         2        0        no    yes  yes
## 32  reputation   mother          2         2        0        no    yes   no
```

```
## 34      course   mother          1          2          0        no     no   no
## 43      course   father          1          2          0        no    yes   no
## 46      course   mother          1          2          0       yes    yes  yes
## 58  reputation   mother          1          2          0        no    yes   no
## 59        home   father          1          2          0       yes    yes   no
## 60      course   mother          1          2          0        no    yes   no
## 72      course   mother          1          4          0        no     no   no
## 76        home   mother          1          2          0        no    yes  yes
## 78  reputation   mother          1          4          0        no     no  yes
## 80      course   mother          1          2          0        no    yes   no
## 89  reputation   father          2          2          1        no     no  yes
## 94        home   mother          2          2          0        no    yes  yes
## 95  reputation   mother          1          4          0        no    yes   no
## 97  reputation   mother          2          1          0       yes    yes   no
## 98      course   mother          1          2          0        no    yes  yes
## 115 reputation   mother          1          2          0        no     no   no
## 116     course   father          1          2          0        no    yes   no
## 119     course   father          3          2          1        no    yes   no
## 120 reputation   father          1          1          0        no     no   no
## 130     course   mother          1          1          0        no     no  yes
## 133     course   father          1          1          0        no    yes   no
## 149     course   mother          1          1          0        no    yes   no
## 150     course   mother          4          1          3        no     no   no
## 152     course   mother          1          1          1        no     no   no
## 155     course   mother          1          1          0       yes    yes   no
## 160     course   father          1          2          1        no    yes  yes
## 174       home   mother          1          2          3        no     no   no
## 175 reputation   mother          2          2          0        no    yes  yes
## 178 reputation   father          1          2          0        no     no   no
## 180     course   mother          1          2          0        no    yes   no
## 187      other   mother          1          1          0        no    yes  yes
## 194 reputation   mother          1          1          0        no    yes   no
## 196     course   father          1          2          0        no     no   no
## 200 reputation   mother          1          2          0        no    yes  yes
## 224       home   mother          2          2          0        no    yes  yes
## 226 reputation   mother          1          2          1        no     no   no
## 227     course   mother          1          2          0        no     no   no
## 229     course   mother          4          2          0       yes    yes  yes
## 231 reputation   father          1          2          0        no     no   no
## 235       home   mother          2          2          0        no    yes  yes
## 239     course   mother          3          2          0        no     no   no
## 240 reputation   father          1          2          1        no     no   no
## 243     course   mother          1          1          0        no     no   no
## 244     course   mother          1          1          0        no     no   no
## 250      other   mother          1          1          0        no     no  yes
## 254     course   mother          2          1          0        no     no   no
## 260     course   father          1          4          0        no     no  yes
## 264       home   mother          1          3          0        no     no   no
## 269 reputation   father          1          2          0        no    yes  yes
## 273       home   mother          2          2          0        no    yes  yes
## 279 reputation   father          1          2          1       yes    yes   no
## 281       home   mother          2          1          0        no     no  yes
## 282       home   mother          1          1          1        no     no   no
## 283 reputation   mother          2          4          0        no    yes  yes
```

```
## 284       home   mother          2         2        0       yes     no   no
## 288 reputation   mother          1         3        0        no    yes  yes
## 292 reputation   mother          1         3        0        no    yes  yes
## 300       home   mother          1         1        0        no    yes  yes
## 304 reputation   father          1         4        0        no    yes  yes
## 315       home    other          1         3        2        no     no   no
## 322     course   mother          1         2        0        no    yes   no
## 328     course   mother          4         1        0        no    yes   no
## 329     course   mother          1         3        0        no    yes  yes
## 336     course   mother          1         3        0        no     no   no
## 340       home   mother          1         2        0        no    yes  yes
## 341       home    other          1         3        1        no     no  yes
## 347     course   mother          1         3        0        no     no   no
## 358 reputation   mother          2         2        0        no     no   no
## 369     course   father          2         1        0        no    yes  yes
## 378     course   mother          1         2        0        no     no  yes
## 385       home   father          2         1        1        no     no  yes
## 386      other   mother          2         3        0        no     no  yes
## 389     course   mother          1         2        0        no    yes  yes
##     activities nursery higher internet romantic famrel freetime goout Dalc Walc
## 11          no     yes    yes      yes       no    low      low   low  low  low
## 17         yes     yes    yes      yes       no    low      low   low  low  low
## 18         yes     yes    yes       no       no   high      low   low  low  low
## 21          no     yes    yes      yes       no   high     high   low  low  low
## 31          no      no    yes      yes       no   high     high   low  low high
## 32         yes     yes    yes      yes       no   high      low   low  low  low
## 34         yes      no    yes      yes       no   high      low   low  low  low
## 43         yes     yes    yes      yes       no   high      low   low  low  low
## 46         yes     yes    yes      yes      yes   high      low   low  low  low
## 58         yes     yes    yes       no       no    low      low   low  low  low
## 59         yes     yes    yes      yes       no   high      low   low  low  low
## 60          no     yes    yes      yes       no   high      low   low  low  low
## 72          no     yes    yes      yes       no    low      low   low  low  low
## 76         yes     yes    yes      yes       no   high      low   low  low  low
## 78          no     yes    yes      yes      yes   high      low   low  low  low
## 80          no     yes    yes      yes       no    low     high   low  low  low
## 89         yes      no    yes      yes       no   high     high   low  low  low
## 94         yes     yes    yes      yes       no   high      low   low  low  low
## 95         yes     yes    yes      yes       no   high      low  high  low  low
## 97         yes      no    yes      yes       no    low      low   low  low  low
## 98          no     yes    yes       no      yes   high      low  high  low  low
## 115        yes     yes    yes      yes      yes   high     high   low  low  low
## 116        yes     yes    yes      yes       no   high     high  high  low  low
## 119        yes     yes    yes      yes       no   high      low  high  low high
## 120         no     yes    yes      yes       no    low     high   low  low  low
## 130        yes     yes    yes      yes       no    low     high  high  low high
## 133         no     yes    yes      yes      yes    low     high  high  low  low
## 149         no     yes     no      yes      yes    low      low   low  low  low
## 150         no     yes    yes      yes       no   high     high  high  low high
## 152        yes     yes    yes       no      yes   high     high  high  low high
## 155         no     yes    yes       no      yes   high      low   low  low  low
## 160         no     yes    yes      yes      yes   high     high  high high high
## 174        yes      no    yes      yes      yes   high      low  high  low  low
## 175        yes     yes    yes      yes       no   high     high  high  low  low
```

```
## 178        yes      no    yes      yes       no   high      low  high  low high
## 180        yes     yes    yes      yes      yes   high      low   low  low  low
## 187        yes     yes    yes      yes      yes    low      low   low  low  low
## 194        yes     yes    yes      yes       no   high      low   low  low high
## 196        yes     yes    yes      yes      yes   high      low   low  low  low
## 200         no     yes    yes      yes       no   high     high   low  low  low
## 224         no     yes    yes      yes       no    low      low   low high high
## 226        yes     yes    yes      yes      yes   high      low   low  low  low
## 227        yes      no    yes      yes       no   high      low  high  low  low
## 229        yes     yes    yes      yes      yes   high      low   low high high
## 231        yes     yes    yes      yes      yes    low      low   low  low  low
## 235         no     yes    yes      yes       no    low     high   low  low  low
## 239        yes     yes    yes       no       no    low      low   low  low  low
## 240         no     yes     no      yes       no   high     high  high  low high
## 243        yes      no    yes      yes       no   high     high  high  low  low
## 244        yes     yes    yes      yes       no   high      low   low  low  low
## 250         no      no    yes      yes       no   high      low   low  low high
## 254        yes      no    yes       no       no    low      low   low  low  low
## 260        yes     yes    yes      yes      yes    low     high   low  low  low
## 264        yes      no    yes       no       no    low      low   low  low  low
## 269        yes     yes    yes      yes      yes   high     high  high  low  low
## 273         no      no    yes       no       no   high     high   low  low  low
## 279        yes     yes    yes      yes      yes    low     high  high  low  low
## 281        yes     yes    yes      yes      yes   high     high  high  low high
## 282         no     yes    yes      yes       no   high     high  high  low high
## 283        yes     yes    yes       no       no   high      low   low  low  low
## 284        yes     yes    yes      yes       no   high     high  high  low  low
## 288         no     yes    yes      yes       no   high      low   low  low  low
## 292         no     yes    yes      yes       no   high      low   low  low  low
## 300         no     yes    yes      yes      yes    low     high   low  low  low
## 304        yes      no    yes      yes       no   high      low   low  low  low
## 315         no      no    yes      yes      yes   high      low   low  low  low
## 322         no     yes    yes       no      yes   high      low   low  low  low
## 328         no     yes    yes      yes       no   high     high  high high high
## 329        yes     yes    yes      yes       no   high     high  high  low  low
## 336         no     yes    yes      yes       no   high     high  high  low  low
## 340         no     yes    yes      yes       no   high      low   low  low  low
## 341        yes     yes    yes      yes      yes   high      low  high  low  low
## 347         no     yes    yes      yes      yes   high      low   low  low  low
## 358         no     yes    yes       no      yes    low      low   low  low  low
## 369         no     yes    yes      yes      yes   high      low   low  low  low
## 378        yes     yes    yes      yes       no   high     high   low  low high
## 385         no     yes    yes       no       no   high     high   low high  low
## 386         no     yes    yes       no       no   high      low   low  low  low
## 389         no     yes    yes      yes       no   high      low  high  low  low
##     health absences G1 G2 G3 first_gen_college stable_learning_env
## 11     low        0 10  8  9                no                 yes
## 17     low        6 13 14 14                no                 yes
## 18    high        4  8 10 10               yes                  no
## 21     low        0 13 14 15                no                  no
## 31    high        0  9 11 12                no                 yes
## 32    high        0 17 16 17                no                 yes
## 34     low        0  8 10 12               yes                  no
## 43    high        2 19 18 18                no                 yes
```

```
## 46    high        8  8  8  6              no              yes
## 58    high        4 14 15 15              no               no
## 59    high        2  9 10  9             yes              yes
## 60    high        2 15 16 16              no              yes
## 72     low        0 10 10 10              no               no
## 76    high        6  9  9 10              no              yes
## 78     low        0 11 11 11             yes               no
## 80     low       12  5  5  5              no              yes
## 89     low       12 11 10 10             yes               no
## 94     low        0 11 10 10              no              yes
## 95    high        6 11 13 14             yes              yes
## 97    high        2 11 15 15              no              yes
## 98    high        2  8  9 10             yes               no
## 115   high        8  9  9  9             yes               no
## 116   high        2 15 15 16              no              yes
## 119   high       20  9  7  8             yes              yes
## 120   high        6 14 13 13              no               no
## 130   high        8 18 18 18              no               no
## 133   high       12 10 13 12             yes              yes
## 149   high        0  7  6  0              no              yes
## 150   high        0  8  9 10             yes               no
## 152   high        6 12 13 14             yes               no
## 155   high        0 11 11 12              no               no
## 160   high        4 10 12 12             yes              yes
## 174    low        0  8  7  0             yes               no
## 175   high        4 10 11  9             yes              yes
## 178   high        4  6  5  6             yes               no
## 180    low        4 10 10 11              no              yes
## 187    low        2 11 12 11             yes              yes
## 194   high        8  8  9 10             yes              yes
## 196   high        0 14 15 15              no               no
## 200    low        0  9  9 10              no              yes
## 224   high        0 12 13 13             yes              yes
## 226   high       16  9  8  7             yes               no
## 227    low       10 16 15 15             yes               no
## 229    low       14 10  8  9             yes              yes
## 231    low       14 13 13 14              no               no
## 235   high       18  9  7  6             yes              yes
## 239    low        2 13 11 11             yes               no
## 240    low        0  7  7  0             yes               no
## 243    low        0  6  0  0              no               no
## 244   high        0 13 12 12              no               no
## 250   high        0 13 15 15             yes               no
## 254    low        0  8  9  8             yes               no
## 260    low        0 10  9  0             yes               no
## 264   high        4 10  9  9             yes               no
## 269   high       10 10  9 10              no              yes
## 273    low        2 11 11 11             yes               no
## 279   high       15  9  8  8              no              yes
## 281   high       30  8  8  8              no               no
## 282    low       19 11  9 10             yes               no
## 283    low        1 12 12 12             yes               no
## 284   high        4  8  9 10             yes               no
## 288    low        6 13 12 12             yes              yes
```

```
## 292    low        0 15 15 15              no                yes
## 300    low        5 16 15 16              no                yes
## 304   high        0 17 17 18             yes                yes
## 315    low       14 15 13 13             yes                 no
## 322    low       12 11  9  9             yes                 no
## 328   high        8 11 10 10             yes                yes
## 329   high        7 10  9  9              no                yes
## 336   high       16 16 15 15              no                 no
## 340    low        4  9 10 10             yes                yes
## 341    low        4 11 12 11             yes                 no
## 347   high        9 16 15 16              no                 no
## 358   high        2 12 12 11             yes                 no
## 369   high        0 11 10 10             yes                yes
## 378    low        4  8  9 10              no                 no
## 385    low       14  6  5  5              no                 no
## 386   high        2 10  9 10             yes                 no
## 389    low        0  7  9  8             yes                yes
##     high_freq_absent failed ord_g3
## 11                no     no      9
## 17                no     no     14
## 18                no     no     10
## 21                no     no     15
## 31                no     no     12
## 32                no     no     17
## 34                no     no     12
## 43                no     no     18
## 46                no     no      6
## 58                no     no     15
## 59                no     no      9
## 60                no     no     16
## 72                no     no     10
## 76                no     no     10
## 78                no     no     11
## 80               yes     no      5
## 89               yes    yes     10
## 94                no     no     10
## 95                no     no     14
## 97                no     no     15
## 98                no     no     10
## 115               no     no      9
## 116               no     no     16
## 119              yes    yes      8
## 120               no     no     13
## 130               no     no     18
## 133              yes     no     12
## 149               no     no      0
## 150               no    yes     10
## 152               no    yes     14
## 155               no     no     12
## 160               no    yes     12
## 174               no    yes      0
## 175               no     no      9
## 178               no     no      6
## 180               no     no     11
```

```
## 187              no     no     11
## 194              no     no     10
## 196              no     no     15
## 200              no     no     10
## 224              no     no     13
## 226             yes    yes      7
## 227             yes     no     15
## 229             yes     no      9
## 231             yes     no     14
## 235             yes     no      6
## 239              no     no     11
## 240              no    yes      0
## 243              no     no      0
## 244              no     no     12
## 250              no     no     15
## 254              no     no      8
## 260              no     no      0
## 264              no     no      9
## 269             yes     no     10
## 273              no     no     11
## 279             yes    yes      8
## 281             yes     no      8
## 282             yes    yes     10
## 283              no     no     12
## 284              no     no     10
## 288              no     no     12
## 292              no     no     15
## 300              no     no     16
## 304              no     no     18
## 315             yes    yes     13
## 322             yes     no      9
## 328              no     no     10
## 329              no     no      9
## 336             yes     no     15
## 340              no     no     10
## 341              no    yes     11
## 347              no     no     16
## 358              no     no     11
## 369              no     no     10
## 378              no     no     10
## 385             yes    yes      5
## 386              no     no     10
## 389              no     no      8
```

### Linear model – note this is incorrect, should be on training set

```
base_lm <- lm(G3 ~ . -G2 -G1 -ord_g3 -stable_learning_env, data)
summary(base_lm)
```

```
##
## Call:
## lm(formula = G3 ~ . - G2 - G1 - ord_g3 - stable_learning_env,
##     data = data)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -12.4629  -1.8563   0.3768   2.7129   8.4183
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)          14.26449    4.83968   2.947  0.00342 **
## schoolMS              0.71627    0.78940   0.907  0.36483
## sexM                  1.24064    0.49743   2.494  0.01309 *
## age                  -0.29977    0.21631  -1.386  0.16667
## addressU              0.50527    0.57951   0.872  0.38386
## famsizeLE3            0.70815    0.48336   1.465  0.14380
## PstatusT             -0.33706    0.72697  -0.464  0.64318
## Medu                  0.19327    0.35893   0.538  0.59060
## Fedu                 -0.24782    0.30312  -0.818  0.41416
## Mjobhealth            0.77671    1.11854   0.694  0.48789
## Mjobother            -0.37068    0.71864  -0.516  0.60631
## Mjobservices          0.77141    0.79944   0.965  0.33524
## Mjobteacher          -1.45523    1.04350  -1.395  0.16402
## Fjobhealth            0.50264    1.43071   0.351  0.72556
## Fjobother            -0.44303    1.01109  -0.438  0.66153
## Fjobservices         -0.28558    1.05170  -0.272  0.78614
## Fjobteacher           1.18454    1.28968   0.918  0.35900
## reasonhome            0.15104    0.55120   0.274  0.78422
## reasonother           0.90615    0.81174   1.116  0.26505
## reasonreputation      0.78970    0.57320   1.378  0.16917
## guardianmother       -0.06654    0.54705  -0.122  0.90326
## guardianother         0.74621    0.99921   0.747  0.45568
## traveltime           -0.33731    0.34177  -0.987  0.32435
## studytime             0.43921    0.28472   1.543  0.12382
## failures             -0.68669    0.59765  -1.149  0.25134
## schoolsupyes         -1.25886    0.66531  -1.892  0.05929 .
## famsupyes            -0.87494    0.47671  -1.835  0.06729 .
## paidyes               0.27979    0.47654   0.587  0.55749
## activitiesyes        -0.27894    0.44015  -0.634  0.52667
## nurseryyes           -0.12389    0.54987  -0.225  0.82188
## higheryes             1.48003    1.08166   1.368  0.17209
## internetyes           0.45356    0.61399   0.739  0.46058
## romanticyes          -1.16064    0.46719  -2.484  0.01345 *
## famrellow            -0.30748    0.51272  -0.600  0.54909
## freetimelow          -0.79441    0.47382  -1.677  0.09450 .
## gooutlow              1.33550    0.51112   2.613  0.00936 **
## Dalclow              -0.21717    1.15359  -0.188  0.85079
## Walclow              -0.02676    0.67033  -0.040  0.96818
## healthlow             0.20864    0.44481   0.469  0.63932
## absences              0.09519    0.04094   2.325  0.02063 *
## first_gen_collegeyes -1.02075    0.79309  -1.287  0.19892
## high_freq_absentyes  -0.77063    0.81373  -0.947  0.34427
## failedyes            -2.27412    1.10329  -2.061  0.04002 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.082 on 352 degrees of freedom
## Multiple R-squared:  0.2907, Adjusted R-squared:  0.2061
```

```
## F-statistic: 3.435 on 42 and 352 DF,  p-value: 1.498e-10
```

```
step.model <- stepAIC(base_lm, direction="both")
```

```
## Start:  AIC=1151.72
## G3 ~ (school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + Fjob + reason + guardian + traveltime + studytime +
##     failures + schoolsup + famsup + paid + activities + nursery +
##     higher + internet + romantic + famrel + freetime + goout +
##     Dalc + Walc + health + absences + G1 + G2 + first_gen_college +
##     stable_learning_env + high_freq_absent + failed + ord_g3) -
##     G2 - G1 - ord_g3 - stable_learning_env
##
##                      Df Sum of Sq    RSS    AIC
## - Fjob                4    58.108 5924.0 1147.6
## - guardian            2    12.927 5878.8 1148.6
## - reason              3    46.316 5912.2 1148.8
## - Walc                1     0.027 5865.9 1149.7
## - Dalc                1     0.591 5866.5 1149.8
## - nursery             1     0.846 5866.7 1149.8
## - Pstatus             1     3.582 5869.5 1150.0
## - health              1     3.666 5869.6 1150.0
## - Medu                1     4.832 5870.7 1150.0
## - paid                1     5.745 5871.6 1150.1
## - famrel              1     5.993 5871.9 1150.1
## - activities          1     6.693 5872.6 1150.2
## - internet            1     9.094 5875.0 1150.3
## - Fedu                1    11.139 5877.0 1150.5
## - address             1    12.668 5878.6 1150.6
## - school              1    13.720 5879.6 1150.6
## - high_freq_absent    1    14.946 5880.8 1150.7
## - traveltime          1    16.232 5882.1 1150.8
## - failures            1    22.000 5887.9 1151.2
## - first_gen_college   1    27.605 5893.5 1151.6
## <none>                           5865.9 1151.7
## - higher              1    31.200 5897.1 1151.8
## - age                 1    32.006 5897.9 1151.9
## - famsize             1    35.768 5901.7 1152.1
## - studytime           1    39.656 5905.5 1152.4
## - freetime            1    46.845 5912.7 1152.9
## - famsup              1    56.136 5922.0 1153.5
## - schoolsup           1    59.662 5925.6 1153.7
## - failed              1    70.801 5936.7 1154.5
## - absences            1    90.094 5956.0 1155.7
## - Mjob                4   192.395 6058.3 1156.5
## - romantic            1   102.848 5968.7 1156.6
## - sex                 1   103.661 5969.6 1156.6
## - goout               1   113.773 5979.7 1157.3
##
## Step:  AIC=1147.61
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + reason + guardian + traveltime + studytime +
##     failures + schoolsup + famsup + paid + activities + nursery +
##     higher + internet + romantic + famrel + freetime + goout +
##     Dalc + Walc + health + absences + first_gen_college + high_freq_absent +
```

```
##     failed
##
##                      Df Sum of Sq    RSS    AIC
## - guardian            2    10.384 5934.4 1144.3
## - reason              3    59.440 5983.4 1145.6
## - Walc                1     0.559 5924.6 1145.7
## - nursery             1     0.970 5925.0 1145.7
## - Dalc                1     1.241 5925.2 1145.7
## - health              1     2.560 5926.6 1145.8
## - Fedu                1     2.588 5926.6 1145.8
## - paid                1     2.969 5927.0 1145.8
## - Medu                1     3.297 5927.3 1145.8
## - famrel              1     4.231 5928.2 1145.9
## - internet            1     5.645 5929.6 1146.0
## - Pstatus             1     5.731 5929.7 1146.0
## - activities          1    10.513 5934.5 1146.3
## - school              1    11.795 5935.8 1146.4
## - address             1    14.753 5938.8 1146.6
## - traveltime          1    14.820 5938.8 1146.6
## - high_freq_absent    1    18.403 5942.4 1146.8
## - failures            1    22.209 5946.2 1147.1
## <none>                            5924.0 1147.6
## - age                 1    30.631 5954.6 1147.7
## - higher              1    30.845 5954.8 1147.7
## - famsize             1    32.187 5956.2 1147.8
## - first_gen_college   1    34.350 5958.4 1147.9
## - studytime           1    43.941 5967.9 1148.5
## - schoolsup           1    49.517 5973.5 1148.9
## - freetime            1    50.138 5974.1 1148.9
## - famsup              1    53.020 5977.0 1149.1
## - failed              1    66.563 5990.6 1150.0
## - Mjob                4   180.518 6104.5 1151.5
## + Fjob                4    58.108 5865.9 1151.7
## - absences            1    94.253 6018.3 1151.8
## - romantic            1    94.936 6018.9 1151.9
## - sex                 1   105.155 6029.2 1152.6
## - goout               1   110.854 6034.9 1152.9
##
## Step:  AIC=1144.3
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + reason + traveltime + studytime + failures +
##     schoolsup + famsup + paid + activities + nursery + higher +
##     internet + romantic + famrel + freetime + goout + Dalc +
##     Walc + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                      Df Sum of Sq    RSS    AIC
## - reason              3    60.268 5994.7 1142.3
## - Walc                1     1.015 5935.4 1142.4
## - Dalc                1     1.194 5935.6 1142.4
## - Fedu                1     1.464 5935.8 1142.4
## - Medu                1     2.315 5936.7 1142.5
## - nursery             1     2.354 5936.7 1142.5
## - paid                1     3.146 5937.5 1142.5
```

```
## - health             1     3.681 5938.1 1142.5
## - famrel             1     4.627 5939.0 1142.6
## - internet           1     5.511 5939.9 1142.7
## - Pstatus            1     6.799 5941.2 1142.8
## - school             1    10.510 5944.9 1143.0
## - activities         1    10.605 5945.0 1143.0
## - traveltime         1    12.005 5946.4 1143.1
## - high_freq_absent   1    18.082 5952.5 1143.5
## - address            1    19.026 5953.4 1143.6
## - failures           1    21.806 5956.2 1143.8
## - age                1    23.499 5957.9 1143.9
## <none>                           5934.4 1144.3
## - famsize            1    30.756 5965.1 1144.3
## - first_gen_college  1    33.861 5968.2 1144.5
## - higher             1    35.225 5969.6 1144.6
## - studytime          1    47.430 5981.8 1145.5
## - schoolsup          1    48.694 5983.1 1145.5
## - famsup             1    51.296 5985.7 1145.7
## - freetime           1    56.659 5991.0 1146.1
## - failed             1    61.246 5995.6 1146.4
## + guardian           2    10.384 5924.0 1147.6
## - Mjob               4   183.657 6118.0 1148.3
## - romantic           1    92.824 6027.2 1148.4
## + Fjob               4    55.565 5878.8 1148.6
## - absences           1    95.558 6029.9 1148.6
## - sex                1   107.385 6041.8 1149.4
## - goout              1   118.595 6053.0 1150.1
##
## Step:  AIC=1142.3
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
##     famsup + paid + activities + nursery + higher + internet +
##     romantic + famrel + freetime + goout + Dalc + Walc + health +
##     absences + first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - Walc               1     1.317 5996.0 1140.4
## - Fedu               1     1.469 5996.1 1140.4
## - Dalc               1     1.838 5996.5 1140.4
## - nursery            1     1.951 5996.6 1140.4
## - Medu               1     3.918 5998.6 1140.5
## - internet           1     4.868 5999.5 1140.6
## - activities         1     6.230 6000.9 1140.7
## - famrel             1     6.241 6000.9 1140.7
## - Pstatus            1     6.498 6001.2 1140.7
## - health             1     6.870 6001.5 1140.8
## - paid               1     7.053 6001.7 1140.8
## - school             1    10.560 6005.2 1141.0
## - address            1    12.612 6007.3 1141.1
## - traveltime         1    13.824 6008.5 1141.2
## - high_freq_absent   1    14.302 6009.0 1141.2
## - age                1    25.650 6020.3 1142.0
## - failures           1    27.179 6021.8 1142.1
## - higher             1    28.065 6022.7 1142.1
```

```
## - famsize            1    29.828 6024.5 1142.3
## <none>                         5994.7 1142.3
## - first_gen_college  1    30.439 6025.1 1142.3
## - schoolsup          1    48.574 6043.2 1143.5
## - studytime          1    50.699 6045.4 1143.6
## - famsup             1    54.155 6048.8 1143.8
## - failed             1    55.751 6050.4 1144.0
## - freetime           1    56.307 6051.0 1144.0
## + reason             3    60.268 5934.4 1144.3
## + guardian           2    11.211 5983.4 1145.6
## + Fjob               4    68.895 5925.8 1145.7
## - romantic           1    91.877 6086.5 1146.3
## - absences           1    96.791 6091.4 1146.6
## - sex                1    99.491 6094.1 1146.8
## - Mjob               4   216.467 6211.1 1148.3
## - goout              1   126.588 6121.2 1148.5
##
## Step:  AIC=1140.38
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
##     famsup + paid + activities + nursery + higher + internet +
##     romantic + famrel + freetime + goout + Dalc + health + absences +
##     first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - Dalc               1     1.109 5997.1 1138.5
## - Fedu               1     1.644 5997.6 1138.5
## - nursery            1     1.737 5997.7 1138.5
## - Medu               1     4.078 6000.0 1138.7
## - internet           1     4.884 6000.9 1138.7
## - activities         1     6.130 6002.1 1138.8
## - Pstatus            1     6.137 6002.1 1138.8
## - paid               1     6.727 6002.7 1138.8
## - famrel             1     7.078 6003.0 1138.8
## - health             1     7.451 6003.4 1138.9
## - school             1    11.132 6007.1 1139.1
## - address            1    13.102 6009.1 1139.2
## - traveltime         1    14.450 6010.4 1139.3
## - high_freq_absent   1    14.481 6010.5 1139.3
## - age                1    24.951 6020.9 1140.0
## - failures           1    27.554 6023.5 1140.2
## - higher             1    28.788 6024.8 1140.3
## - famsize            1    29.376 6025.3 1140.3
## <none>                         5996.0 1140.4
## - first_gen_college  1    30.478 6026.4 1140.4
## - schoolsup          1    47.915 6043.9 1141.5
## - studytime          1    51.565 6047.5 1141.8
## - famsup             1    53.086 6049.1 1141.9
## - failed             1    55.730 6051.7 1142.0
## - freetime           1    57.401 6053.4 1142.2
## + Walc               1     1.317 5994.7 1142.3
## + reason             3    60.569 5935.4 1142.4
## + guardian           2    11.743 5984.2 1143.6
## + Fjob               4    70.097 5925.9 1143.7
```

```
## - romantic           1    90.982 6087.0 1144.3
## - absences           1    95.639 6091.6 1144.6
## - sex                1    99.432 6095.4 1144.9
## - Mjob               4   217.116 6213.1 1146.4
## - goout              1   159.887 6155.9 1148.8
##
## Step:  AIC=1138.46
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
##     famsup + paid + activities + nursery + higher + internet +
##     romantic + famrel + freetime + goout + health + absences +
##     first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - Fedu               1     1.590 5998.7 1136.6
## - nursery            1     2.133 5999.2 1136.6
## - Medu               1     4.304 6001.4 1136.7
## - internet           1     4.928 6002.0 1136.8
## - activities         1     6.292 6003.4 1136.9
## - Pstatus            1     6.388 6003.5 1136.9
## - famrel             1     6.962 6004.0 1136.9
## - health             1     7.081 6004.2 1136.9
## - paid               1     7.849 6004.9 1137.0
## - school             1    11.411 6008.5 1137.2
## - address            1    13.515 6010.6 1137.3
## - high_freq_absent   1    13.555 6010.6 1137.3
## - traveltime         1    13.601 6010.7 1137.3
## - age                1    24.411 6021.5 1138.1
## - failures           1    27.503 6024.6 1138.3
## - higher             1    29.028 6026.1 1138.4
## - famsize            1    29.269 6026.3 1138.4
## - first_gen_college  1    30.243 6027.3 1138.4
## <none>                           5997.1 1138.5
## - schoolsup          1    47.036 6044.1 1139.5
## - studytime          1    51.478 6048.6 1139.8
## - famsup             1    52.900 6050.0 1139.9
## - failed             1    56.066 6053.1 1140.1
## - freetime           1    58.687 6055.8 1140.3
## + Dalc               1     1.109 5996.0 1140.4
## + Walc               1     0.588 5996.5 1140.4
## + reason             3    60.996 5936.1 1140.4
## + guardian           2    11.494 5985.6 1141.7
## + Fjob               4    70.556 5926.5 1141.8
## - romantic           1    89.994 6087.1 1142.3
## - absences           1    94.651 6091.7 1142.6
## - sex                1   106.450 6103.5 1143.4
## - Mjob               4   217.084 6214.2 1144.5
## - goout              1   158.780 6155.9 1146.8
##
## Step:  AIC=1136.56
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Mjob + traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + nursery + higher + internet + romantic +
##     famrel + freetime + goout + health + absences + first_gen_college +
```

```
##     high_freq_absent + failed
##
##                      Df Sum of Sq    RSS    AIC
## - nursery             1     2.229 6000.9 1134.7
## - Medu                1     3.471 6002.1 1134.8
## - internet            1     4.751 6003.4 1134.9
## - Pstatus             1     6.265 6004.9 1135.0
## - activities          1     6.509 6005.2 1135.0
## - famrel              1     6.807 6005.5 1135.0
## - health              1     7.276 6005.9 1135.0
## - paid                1     8.368 6007.0 1135.1
## - school              1    10.964 6009.6 1135.3
## - traveltime          1    12.621 6011.3 1135.4
## - high_freq_absent    1    12.860 6011.5 1135.4
## - address             1    13.704 6012.4 1135.5
## - age                 1    24.490 6023.2 1136.2
## - failures            1    26.412 6025.1 1136.3
## - higher              1    28.308 6027.0 1136.4
## - famsize             1    29.765 6028.4 1136.5
## - first_gen_college   1    30.436 6029.1 1136.6
## <none>                           5998.7 1136.6
## - schoolsup           1    47.826 6046.5 1137.7
## - studytime           1    54.191 6052.9 1138.1
## - famsup              1    56.277 6054.9 1138.2
## - failed              1    57.385 6056.1 1138.3
## + Fedu                1     1.590 5997.1 1138.5
## + Dalc                1     1.055 5997.6 1138.5
## + Walc                1     0.713 5998.0 1138.5
## + reason              3    61.019 5937.6 1138.5
## - freetime            1    60.685 6059.4 1138.5
## + guardian            2    10.228 5988.4 1139.9
## - romantic            1    89.702 6088.4 1140.4
## + Fjob                4    61.291 5937.4 1140.5
## - absences            1    93.526 6092.2 1140.7
## - sex                 1   106.050 6104.7 1141.5
## - Mjob                4   216.236 6214.9 1142.5
## - goout               1   161.916 6160.6 1145.1
##
## Step:  AIC=1134.71
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Mjob + traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + higher + internet + romantic + famrel +
##     freetime + goout + health + absences + first_gen_college +
##     high_freq_absent + failed
##
##                      Df Sum of Sq    RSS    AIC
## - Medu                1     3.280 6004.2 1132.9
## - internet            1     5.167 6006.1 1133.0
## - Pstatus             1     5.949 6006.8 1133.1
## - activities          1     6.240 6007.1 1133.1
## - famrel              1     6.524 6007.4 1133.1
## - health              1     7.491 6008.4 1133.2
## - paid                1     7.883 6008.8 1133.2
## - school              1    11.399 6012.3 1133.5
```

```
## - traveltime         1    12.798 6013.7 1133.5
## - high_freq_absent   1    13.147 6014.0 1133.6
## - address            1    13.559 6014.5 1133.6
## - age                1    24.023 6024.9 1134.3
## - failures           1    26.018 6026.9 1134.4
## - famsize            1    28.442 6029.3 1134.6
## - higher             1    28.613 6029.5 1134.6
## - first_gen_college  1    29.504 6030.4 1134.6
## <none>                           6000.9 1134.7
## - schoolsup          1    48.791 6049.7 1135.9
## - studytime          1    52.898 6053.8 1136.2
## - famsup             1    56.130 6057.0 1136.4
## - failed             1    57.614 6058.5 1136.5
## + nursery            1     2.229 5998.7 1136.6
## + Fedu               1     1.686 5999.2 1136.6
## + Dalc               1     1.451 5999.4 1136.6
## + Walc               1     0.466 6000.4 1136.7
## + reason             3    60.661 5940.2 1136.7
## - freetime           1    61.848 6062.7 1136.8
## + guardian           2    11.467 5989.4 1138.0
## - romantic           1    90.641 6091.5 1138.6
## + Fjob               4    61.040 5939.9 1138.7
## - absences           1    93.825 6094.7 1138.8
## - sex                1   105.719 6106.6 1139.6
## - Mjob               4   215.495 6216.4 1140.6
## - goout              1   163.450 6164.3 1143.3
##
## Step:  AIC=1132.92
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + higher + internet + romantic + famrel +
##     freetime + goout + health + absences + first_gen_college +
##     high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - internet           1     4.974 6009.2 1131.2
## - activities         1     6.204 6010.4 1131.3
## - Pstatus            1     6.921 6011.1 1131.4
## - famrel             1     7.053 6011.2 1131.4
## - paid               1     7.813 6012.0 1131.4
## - health             1     8.650 6012.8 1131.5
## - school             1    11.485 6015.7 1131.7
## - high_freq_absent   1    12.445 6016.6 1131.7
## - traveltime         1    13.540 6017.7 1131.8
## - address            1    13.940 6018.1 1131.8
## - age                1    24.508 6028.7 1132.5
## - failures           1    26.253 6030.4 1132.7
## - famsize            1    26.629 6030.8 1132.7
## - higher             1    28.529 6032.7 1132.8
## <none>                           6004.2 1132.9
## - schoolsup          1    49.290 6053.5 1134.2
## - famsup             1    54.249 6058.4 1134.5
## - studytime          1    55.376 6059.6 1134.5
## + Medu               1     3.280 6000.9 1134.7
```

```
## + nursery            1     2.038 6002.1 1134.8
## - failed             1    59.069 6063.2 1134.8
## + reason             3    62.168 5942.0 1134.8
## + Dalc               1     1.674 6002.5 1134.8
## + Fedu               1     0.838 6003.3 1134.9
## - freetime           1    60.465 6064.6 1134.9
## + Walc               1     0.486 6003.7 1134.9
## - first_gen_college  1    72.647 6076.8 1135.7
## + guardian           2    10.588 5993.6 1136.2
## - romantic           1    89.697 6093.9 1136.8
## + Fjob               4    60.982 5943.2 1136.9
## - absences           1    97.391 6101.6 1137.3
## - sex                1   108.378 6112.6 1138.0
## - Mjob               4   218.135 6222.3 1139.0
## - goout              1   161.253 6165.4 1141.4
##
## Step:  AIC=1131.25
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + higher + romantic + famrel + freetime +
##     goout + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## - Pstatus            1     5.758 6014.9 1129.6
## - activities         1     6.067 6015.2 1129.7
## - famrel             1     7.719 6016.9 1129.8
## - paid               1     9.030 6018.2 1129.8
## - health             1     9.542 6018.7 1129.9
## - school             1    11.340 6020.5 1130.0
## - high_freq_absent   1    11.969 6021.1 1130.0
## - traveltime         1    13.664 6022.8 1130.2
## - address            1    16.917 6026.1 1130.4
## - failures           1    25.245 6034.4 1130.9
## - famsize            1    26.447 6035.6 1131.0
## - age                1    26.726 6035.9 1131.0
## - higher             1    27.484 6036.6 1131.0
## <none>                           6009.2 1131.2
## - schoolsup          1    49.694 6058.8 1132.5
## - famsup             1    53.344 6062.5 1132.7
## + internet           1     4.974 6004.2 1132.9
## - studytime          1    57.740 6066.9 1133.0
## + Medu               1     3.088 6006.1 1133.0
## + nursery            1     2.435 6006.7 1133.1
## + Dalc               1     1.768 6007.4 1133.1
## - freetime           1    59.458 6068.6 1133.1
## + reason             3    61.415 5947.7 1133.2
## + Fedu               1     0.735 6008.4 1133.2
## + Walc               1     0.461 6008.7 1133.2
## - failed             1    61.239 6070.4 1133.3
## - first_gen_college  1    73.519 6082.7 1134.0
## + guardian           2    10.612 5998.5 1134.5
## - romantic           1    86.466 6095.6 1134.9
## + Fjob               4    57.783 5951.4 1135.4
```

```
## - absences           1   100.838 6110.0 1135.8
## - sex                1   111.435 6120.6 1136.5
## - Mjob               4   221.815 6231.0 1137.6
## - goout              1   159.583 6168.7 1139.6
##
## Step:  AIC=1129.63
## G3 ~ school + sex + age + address + famsize + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + paid + activities +
##     higher + romantic + famrel + freetime + goout + health +
##     absences + first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - famrel             1     7.528 6022.4 1128.1
## - activities         1     7.590 6022.5 1128.1
## - paid               1     8.219 6023.1 1128.2
## - health             1     9.145 6024.1 1128.2
## - school             1    10.994 6025.9 1128.3
## - high_freq_absent   1    12.063 6027.0 1128.4
## - traveltime         1    14.038 6028.9 1128.5
## - address            1    16.902 6031.8 1128.7
## - failures           1    24.055 6039.0 1129.2
## - age                1    27.173 6042.1 1129.4
## - higher             1    28.849 6043.8 1129.5
## <none>                           6014.9 1129.6
## - famsize            1    31.277 6046.2 1129.7
## - schoolsup          1    48.815 6063.7 1130.8
## - famsup             1    53.992 6068.9 1131.2
## + Pstatus            1     5.758 6009.2 1131.2
## - freetime           1    56.915 6071.8 1131.3
## + Medu               1     3.970 6010.9 1131.4
## + internet           1     3.812 6011.1 1131.4
## - studytime          1    57.652 6072.6 1131.4
## + Dalc               1     2.052 6012.9 1131.5
## + nursery            1     2.034 6012.9 1131.5
## + reason             3    61.467 5953.4 1131.6
## + Fedu               1     0.587 6014.3 1131.6
## + Walc               1     0.251 6014.7 1131.6
## - failed             1    63.224 6078.1 1131.8
## - first_gen_college  1    79.217 6094.1 1132.8
## + guardian           2    11.389 6003.5 1132.9
## - romantic           1    85.462 6100.4 1133.2
## + Fjob               4    59.633 5955.3 1133.7
## - absences           1   106.295 6121.2 1134.5
## - sex                1   111.160 6126.1 1134.9
## - Mjob               4   225.315 6240.2 1136.2
## - goout              1   158.110 6173.0 1137.9
##
## Step:  AIC=1128.12
## G3 ~ school + sex + age + address + famsize + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + paid + activities +
##     higher + romantic + freetime + goout + health + absences +
##     first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
```

```
## - activities         1     7.435 6029.9 1126.6
## - health             1     7.584 6030.0 1126.6
## - paid               1     9.149 6031.6 1126.7
## - school             1     9.664 6032.1 1126.8
## - traveltime         1    13.537 6036.0 1127.0
## - high_freq_absent   1    14.005 6036.4 1127.0
## - address            1    17.905 6040.3 1127.3
## - age                1    24.406 6046.8 1127.7
## - failures           1    25.641 6048.1 1127.8
## - higher             1    29.910 6052.3 1128.1
## <none>                           6022.4 1128.1
## - famsize            1    31.152 6053.6 1128.2
## - schoolsup          1    48.344 6070.8 1129.3
## - famsup             1    53.199 6075.6 1129.6
## + famrel             1     7.528 6014.9 1129.6
## + Pstatus            1     5.567 6016.9 1129.8
## + Medu               1     4.536 6017.9 1129.8
## + internet           1     4.405 6018.0 1129.8
## + reason             3    63.460 5959.0 1129.9
## + Dalc               1     1.879 6020.6 1130.0
## + nursery            1     1.761 6020.7 1130.0
## - studytime          1    60.428 6082.9 1130.1
## + Walc               1     0.714 6021.7 1130.1
## + Fedu               1     0.445 6022.0 1130.1
## - freetime           1    61.557 6084.0 1130.1
## - failed             1    61.850 6084.3 1130.2
## + guardian           2    12.164 6010.3 1131.3
## - first_gen_college  1    80.105 6102.5 1131.3
## - romantic           1    85.144 6107.6 1131.7
## + Fjob               4    57.663 5964.8 1132.3
## - absences           1   108.680 6131.1 1133.2
## - sex                1   113.609 6136.0 1133.5
## - Mjob               4   225.936 6248.4 1134.7
## - goout              1   156.890 6179.3 1136.3
##
## Step:  AIC=1126.61
## G3 ~ school + sex + age + address + famsize + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + paid + higher +
##     romantic + freetime + goout + health + absences + first_gen_college +
##     high_freq_absent + failed
##
##                      Df Sum of Sq    RSS    AIC
## - health              1     7.995 6037.9 1125.1
## - paid                1     9.999 6039.9 1125.3
## - school              1    11.483 6041.4 1125.4
## - high_freq_absent    1    13.124 6043.0 1125.5
## - traveltime          1    13.727 6043.6 1125.5
## - address             1    20.017 6049.9 1125.9
## - age                 1    23.452 6053.3 1126.1
## - failures            1    24.299 6054.2 1126.2
## - higher              1    27.659 6057.5 1126.4
## <none>                           6029.9 1126.6
## - famsize             1    31.219 6061.1 1126.7
## - schoolsup           1    50.051 6079.9 1127.9
```

```
## - famsup             1    51.843 6081.7 1128.0
## + activities         1     7.435 6022.4 1128.1
## + famrel             1     7.372 6022.5 1128.1
## + Pstatus            1     7.052 6022.8 1128.2
## - studytime          1    56.694 6086.6 1128.3
## + Medu               1     4.622 6025.3 1128.3
## + internet           1     4.114 6025.8 1128.3
## + Dalc               1     2.101 6027.8 1128.5
## + nursery            1     1.458 6028.4 1128.5
## + Walc               1     0.583 6029.3 1128.6
## + Fedu               1     0.555 6029.3 1128.6
## - freetime           1    61.065 6090.9 1128.6
## + reason             3    58.641 5971.2 1128.8
## - failed             1    63.924 6093.8 1128.8
## - first_gen_college  1    78.223 6108.1 1129.7
## + guardian           2    12.095 6017.8 1129.8
## - romantic           1    88.630 6118.5 1130.4
## + Fjob               4    60.550 5969.3 1130.6
## - absences           1   107.390 6137.3 1131.6
## - sex                1   108.674 6138.5 1131.7
## - Mjob               4   225.207 6255.1 1133.1
## - goout              1   161.707 6191.6 1135.1
##
## Step:  AIC=1125.13
## G3 ~ school + sex + age + address + famsize + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + paid + higher +
##     romantic + freetime + goout + absences + first_gen_college +
##     high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - paid               1    10.716 6048.6 1123.8
## - high_freq_absent   1    11.598 6049.5 1123.9
## - school             1    12.514 6050.4 1124.0
## - traveltime         1    13.912 6051.8 1124.0
## - address            1    21.600 6059.5 1124.5
## - age                1    22.034 6059.9 1124.6
## - failures           1    23.340 6061.2 1124.7
## - higher             1    27.393 6065.3 1124.9
## <none>                           6037.9 1125.1
## - famsize            1    31.772 6069.6 1125.2
## - schoolsup          1    48.738 6086.6 1126.3
## + health             1     7.995 6029.9 1126.6
## + activities         1     7.846 6030.0 1126.6
## - famsup             1    53.732 6091.6 1126.6
## + Pstatus            1     6.708 6031.2 1126.7
## + Medu               1     5.799 6032.1 1126.8
## + famrel             1     5.787 6032.1 1126.8
## + internet           1     4.816 6033.1 1126.8
## - freetime           1    58.585 6096.5 1127.0
## - studytime          1    59.536 6097.4 1127.0
## + nursery            1     1.671 6036.2 1127.0
## + Dalc               1     1.623 6036.2 1127.0
## + reason             3    61.887 5976.0 1127.1
## + Walc               1     1.035 6036.8 1127.1
```

```
## + Fedu               1     0.606 6037.3 1127.1
## - failed             1    66.411 6104.3 1127.5
## + guardian           2    14.111 6023.8 1128.2
## - first_gen_college  1    78.383 6116.3 1128.2
## - romantic           1    90.039 6127.9 1129.0
## + Fjob               4    58.303 5979.6 1129.3
## - sex                1   105.710 6143.6 1130.0
## - absences           1   105.891 6143.8 1130.0
## - Mjob               4   220.425 6258.3 1131.3
## - goout              1   165.403 6203.3 1133.8
##
## Step:  AIC=1123.83
## G3 ~ school + sex + age + address + famsize + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + higher + romantic +
##     freetime + goout + absences + first_gen_college + high_freq_absent +
##     failed
##
##                      Df Sum of Sq    RSS    AIC
## - high_freq_absent   1    11.893 6060.5 1122.6
## - school             1    13.648 6062.2 1122.7
## - traveltime         1    14.707 6063.3 1122.8
## - age                1    20.993 6069.6 1123.2
## - address            1    22.351 6070.9 1123.3
## - failures           1    23.406 6072.0 1123.4
## <none>                           6048.6 1123.8
## - higher             1    31.507 6080.1 1123.9
## - famsize            1    32.108 6080.7 1123.9
## - famsup             1    45.157 6093.7 1124.8
## - schoolsup          1    50.481 6099.1 1125.1
## + paid               1    10.716 6037.9 1125.1
## + activities         1     8.770 6039.8 1125.3
## + health             1     8.713 6039.9 1125.3
## + famrel             1     6.604 6042.0 1125.4
## + reason             3    67.181 5981.4 1125.4
## + internet           1     6.288 6042.3 1125.4
## + Pstatus            1     5.780 6042.8 1125.5
## + Medu               1     5.668 6042.9 1125.5
## - freetime           1    57.147 6105.7 1125.5
## + Dalc               1     3.067 6045.5 1125.6
## + nursery            1     1.236 6047.3 1125.8
## + Fedu               1     0.985 6047.6 1125.8
## + Walc               1     0.555 6048.0 1125.8
## - studytime          1    64.142 6112.7 1126.0
## - failed             1    70.758 6119.3 1126.4
## - first_gen_college  1    77.297 6125.9 1126.8
## + guardian           2    14.405 6034.2 1126.9
## - romantic           1    89.248 6137.8 1127.6
## + Fjob               4    52.599 5996.0 1128.4
## - sex                1   102.339 6150.9 1128.5
## - absences           1   107.768 6156.4 1128.8
## - Mjob               4   219.664 6268.2 1129.9
## - goout              1   160.633 6209.2 1132.2
##
## Step:  AIC=1122.61
```

```
## G3 ~ school + sex + age + address + famsize + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + higher + romantic +
##     freetime + goout + absences + first_gen_college + failed
##
##                      Df Sum of Sq    RSS    AIC
## - traveltime          1    13.259 6073.7 1121.5
## - school              1    14.199 6074.7 1121.5
## - address             1    19.683 6080.2 1121.9
## - failures            1    23.090 6083.6 1122.1
## - age                 1    24.292 6084.8 1122.2
## - higher              1    27.693 6088.2 1122.4
## - famsize             1    29.953 6090.4 1122.6
## <none>                           6060.5 1122.6
## - famsup              1    46.840 6107.3 1123.7
## - schoolsup           1    48.944 6109.4 1123.8
## + high_freq_absent    1    11.893 6048.6 1123.8
## + paid                1    11.012 6049.5 1123.9
## + famrel              1     8.447 6052.0 1124.1
## + activities          1     7.823 6052.7 1124.1
## - freetime            1    54.175 6114.7 1124.1
## + health              1     7.106 6053.4 1124.2
## + internet            1     5.790 6054.7 1124.2
## + Pstatus             1     5.784 6054.7 1124.2
## + Medu                1     4.718 6055.8 1124.3
## + reason              3    63.156 5997.3 1124.5
## + nursery             1     1.403 6059.1 1124.5
## + Dalc                1     1.390 6059.1 1124.5
## + Walc                1     0.944 6059.5 1124.5
## + Fedu                1     0.522 6060.0 1124.6
## - studytime           1    67.327 6127.8 1125.0
## - first_gen_college   1    73.000 6133.5 1125.3
## - failed              1    74.711 6135.2 1125.5
## + guardian            2    14.839 6045.6 1125.6
## - romantic            1    90.329 6150.8 1126.5
## + Fjob                4    54.936 6005.5 1127.0
## - sex                 1   101.693 6162.2 1127.2
## - Mjob                4   214.393 6274.9 1128.3
## - absences            1   128.452 6188.9 1128.9
## - goout               1   162.672 6223.2 1131.1
##
## Step:  AIC=1121.47
## G3 ~ school + sex + age + address + famsize + Mjob + studytime +
##     failures + schoolsup + famsup + higher + romantic + freetime +
##     goout + absences + first_gen_college + failed
##
##                      Df Sum of Sq    RSS    AIC
## - school              1    10.285 6084.0 1120.1
## - age                 1    22.293 6096.0 1120.9
## - failures            1    25.256 6099.0 1121.1
## - famsize             1    26.818 6100.6 1121.2
## - higher              1    28.844 6102.6 1121.3
## <none>                           6073.7 1121.5
## - address             1    31.581 6105.3 1121.5
## + traveltime          1    13.259 6060.5 1122.6
```

```
## - schoolsup          1    49.034 6122.8 1122.7
## + paid               1    11.759 6062.0 1122.7
## - famsup             1    50.943 6124.7 1122.8
## + high_freq_absent   1    10.446 6063.3 1122.8
## + activities         1     8.106 6065.6 1123.0
## + famrel             1     7.816 6065.9 1123.0
## + health             1     7.390 6066.3 1123.0
## - freetime           1    55.528 6129.3 1123.1
## + Pstatus            1     6.136 6067.6 1123.1
## + internet           1     5.946 6067.8 1123.1
## + Medu               1     5.657 6068.1 1123.1
## + reason             3    65.406 6008.3 1123.2
## + Walc               1     1.643 6072.1 1123.4
## + nursery            1     1.504 6072.2 1123.4
## + Dalc               1     0.543 6073.2 1123.4
## + Fedu               1     0.055 6073.7 1123.5
## - studytime          1    71.853 6145.6 1124.1
## - failed             1    71.972 6145.7 1124.1
## - first_gen_college  1    74.364 6148.1 1124.3
## + guardian           2    12.487 6061.3 1124.7
## - romantic           1    92.108 6165.8 1125.4
## - sex                1    98.165 6171.9 1125.8
## + Fjob               4    55.338 6018.4 1125.9
## - Mjob               4   221.092 6294.8 1127.6
## - absences           1   128.487 6202.2 1127.7
## - goout              1   169.495 6243.2 1130.3
##
## Step:  AIC=1120.14
## G3 ~ sex + age + address + famsize + Mjob + studytime + failures +
##     schoolsup + famsup + higher + romantic + freetime + goout +
##     absences + first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## - age                1    14.853 6098.9 1119.1
## - address            1    24.577 6108.6 1119.7
## - failures           1    26.417 6110.4 1119.8
## - famsize            1    29.156 6113.2 1120.0
## <none>                           6084.0 1120.1
## - higher             1    31.483 6115.5 1120.2
## + paid               1    12.688 6071.3 1121.3
## - schoolsup          1    50.582 6134.6 1121.4
## + high_freq_absent   1    11.091 6072.9 1121.4
## + school             1    10.285 6073.7 1121.5
## + activities         1     9.919 6074.1 1121.5
## + traveltime         1     9.345 6074.7 1121.5
## + health             1     8.255 6075.8 1121.6
## + famrel             1     6.463 6077.6 1121.7
## + Pstatus            1     5.867 6078.2 1121.8
## + internet           1     5.813 6078.2 1121.8
## - famsup             1    56.178 6140.2 1121.8
## + Medu               1     5.582 6078.4 1121.8
## - freetime           1    57.740 6141.8 1121.9
## + reason             3    65.002 6019.0 1121.9
## + Walc               1     1.832 6082.2 1122.0
```

```
## + nursery            1     1.823 6082.2 1122.0
## + Dalc               1     0.903 6083.1 1122.1
## + Fedu               1     0.023 6084.0 1122.1
## - studytime          1    65.829 6149.9 1122.4
## - failed             1    71.247 6155.3 1122.7
## - first_gen_college  1    73.351 6157.4 1122.9
## + guardian           2    11.176 6072.8 1123.4
## - romantic           1    89.829 6173.9 1123.9
## - sex                1    93.837 6177.9 1124.2
## + Fjob               4    56.297 6027.7 1124.5
## - absences           1   119.451 6203.5 1125.8
## - Mjob               4   218.306 6302.3 1126.1
## - goout              1   173.743 6257.8 1129.3
##
## Step:  AIC=1119.1
## G3 ~ sex + address + famsize + Mjob + studytime + failures +
##     schoolsup + famsup + higher + romantic + freetime + goout +
##     absences + first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## - failures           1    25.369 6124.2 1118.7
## - famsize            1    28.020 6126.9 1118.9
## - address            1    29.428 6128.3 1119.0
## <none>                           6098.9 1119.1
## - higher             1    37.542 6136.4 1119.5
## - schoolsup          1    39.918 6138.8 1119.7
## + age                1    14.853 6084.0 1120.1
## + high_freq_absent   1    13.491 6085.4 1120.2
## + paid               1    11.222 6087.7 1120.4
## - famsup             1    51.416 6150.3 1120.4
## + traveltime         1     9.314 6089.6 1120.5
## + activities         1     7.916 6091.0 1120.6
## + internet           1     7.349 6091.5 1120.6
## + health             1     6.386 6092.5 1120.7
## + Pstatus            1     6.330 6092.5 1120.7
## + Medu               1     5.734 6093.1 1120.7
## - freetime           1    56.506 6155.4 1120.8
## + famrel             1     5.089 6093.8 1120.8
## + reason             3    65.484 6033.4 1120.8
## + school             1     2.845 6096.0 1120.9
## + nursery            1     1.437 6097.4 1121.0
## + Walc               1     1.141 6097.7 1121.0
## + Dalc               1     0.330 6098.5 1121.1
## + Fedu               1     0.032 6098.8 1121.1
## - studytime          1    62.167 6161.0 1121.1
## - first_gen_college  1    80.992 6179.9 1122.3
## - failed             1    81.064 6179.9 1122.3
## + guardian           2     3.431 6095.4 1122.9
## + Fjob               4    56.965 6041.9 1123.4
## - romantic           1    98.243 6197.1 1123.4
## - sex                1   100.196 6199.1 1123.5
## - absences           1   110.458 6209.3 1124.2
## - Mjob               4   224.920 6323.8 1125.4
## - goout              1   186.393 6285.3 1129.0
```

```
##
## Step:  AIC=1118.74
## G3 ~ sex + address + famsize + Mjob + studytime + schoolsup +
##     famsup + higher + romantic + freetime + goout + absences +
##     first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## - address            1     28.92 6153.2 1118.6
## - famsize            1     29.58 6153.8 1118.7
## <none>                           6124.2 1118.7
## + failures           1     25.37 6098.9 1119.1
## - schoolsup          1     39.39 6163.6 1119.3
## + age                1     13.81 6110.4 1119.8
## + high_freq_absent   1     12.96 6111.3 1119.9
## - higher             1     50.12 6174.4 1120.0
## + paid               1     11.45 6112.8 1120.0
## + traveltime         1     10.94 6113.3 1120.0
## + reason             3     71.38 6052.9 1120.1
## - famsup             1     54.90 6179.1 1120.3
## + activities         1      6.67 6117.6 1120.3
## + famrel             1      6.41 6117.8 1120.3
## + internet           1      6.29 6118.0 1120.3
## + Medu               1      5.99 6118.3 1120.4
## + health             1      5.64 6118.6 1120.4
## + Pstatus            1      4.91 6119.3 1120.4
## - freetime           1     58.15 6182.4 1120.5
## + school             1      3.60 6120.6 1120.5
## + Walc               1      1.63 6122.6 1120.6
## + nursery            1      1.15 6123.1 1120.7
## + Dalc               1      0.28 6124.0 1120.7
## + Fedu               1      0.16 6124.1 1120.7
## - studytime          1     68.48 6192.7 1121.1
## - first_gen_college  1     83.32 6207.6 1122.1
## + guardian           2      3.27 6121.0 1122.5
## + Fjob               4     60.07 6064.2 1122.8
## - romantic           1     98.67 6222.9 1123.1
## - sex                1    103.72 6228.0 1123.4
## - absences           1    127.06 6251.3 1124.9
## - Mjob               4    223.16 6347.4 1124.9
## - goout              1    194.44 6318.7 1129.1
## - failed             1    640.58 6764.8 1156.0
##
## Step:  AIC=1118.61
## G3 ~ sex + famsize + Mjob + studytime + schoolsup + famsup +
##     higher + romantic + freetime + goout + absences + first_gen_college +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## <none>                           6153.2 1118.6
## + address            1     28.92 6124.2 1118.7
## - famsize            1     33.82 6187.0 1118.8
## - schoolsup          1     37.38 6190.5 1119.0
## + failures           1     24.86 6128.3 1119.0
## + traveltime         1     23.30 6129.9 1119.1
```

```
## + age                1     18.47 6134.7 1119.4
## - higher             1     49.47 6202.6 1119.8
## + paid               1     12.04 6141.1 1119.8
## + internet           1     11.88 6141.3 1119.8
## + high_freq_absent   1      8.90 6144.3 1120.0
## + activities         1      8.59 6144.6 1120.0
## - famsup             1     54.87 6208.0 1120.1
## + Medu               1      7.64 6145.5 1120.1
## + famrel             1      7.32 6145.8 1120.1
## + health             1      7.07 6146.1 1120.2
## + Pstatus            1      5.39 6147.8 1120.3
## - freetime           1     57.29 6210.5 1120.3
## + Walc               1      2.41 6150.8 1120.5
## + reason             3     63.85 6089.3 1120.5
## + nursery            1      0.88 6152.3 1120.5
## + Dalc               1      0.33 6152.8 1120.6
## + Fedu               1      0.20 6153.0 1120.6
## + school             1      0.10 6153.1 1120.6
## - studytime          1     64.86 6218.0 1120.8
## - first_gen_college  1     84.51 6237.7 1122.0
## + guardian           2      5.72 6147.4 1122.2
## + Fjob               4     62.03 6091.1 1122.6
## - romantic           1     96.69 6249.9 1122.8
## - sex                1     97.75 6250.9 1122.8
## - absences           1    123.11 6276.3 1124.4
## - Mjob               4    242.27 6395.4 1125.9
## - goout              1    189.15 6342.3 1128.6
## - failed             1    670.10 6823.3 1157.4
```

```
summary(step.model)
```

```
##
## Call:
## lm(formula = G3 ~ sex + famsize + Mjob + studytime + schoolsup +
##     famsup + higher + romantic + freetime + goout + absences +
##     first_gen_college + failed, data = data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.2041  -2.0732   0.3544   2.6786   9.6991
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)          8.11450    1.39218   5.829 1.20e-08 ***
## sexM                 1.12016    0.45712   2.450 0.014719 *
## famsizeLE3           0.65890    0.45713   1.441 0.150309
## Mjobhealth           1.68430    0.93895   1.794 0.073641 .
## Mjobother            0.05209    0.63950   0.081 0.935123
## Mjobservices         1.36030    0.68184   1.995 0.046757 *
## Mjobteacher         -0.71854    0.87864  -0.818 0.413992
## studytime            0.52329    0.26215   1.996 0.046634 *
## schoolsupyes        -0.94383    0.62288  -1.515 0.130542
## famsupyes           -0.80258    0.43716  -1.836 0.067160 .
## higheryes            1.73643    0.99609   1.743 0.082102 .
## romanticyes         -1.09643    0.44989  -2.437 0.015265 *
```

```
## freetimelow          -0.84135    0.44848  -1.876 0.061429 .
## gooutlow              1.53330    0.44981   3.409 0.000723 ***
## absences              0.07208    0.02621   2.750 0.006245 **
## first_gen_collegeyes -1.19608    0.52493  -2.279 0.023250 *
## failedyes            -3.51954    0.54855  -6.416 4.19e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.035 on 378 degrees of freedom
## Multiple R-squared:  0.256,  Adjusted R-squared:  0.2245
## F-statistic: 8.127 on 16 and 378 DF,  p-value: < 2.2e-16
```

From fitting the base variables in a linear model, we can see that the variables sex, schoolsup, famsup, romantic, freetime, goout, absences, and failed are active.

Based on the backwards stepwise regression model, it seems that the variables sex, Mjob, studytime, higher, romantic, freetime, goout, absences, first_gen_college, famsup, failed.

Based on these active variables, some interactions that we think could be significant are: schoolsup*failed,* *famsup*first_gen_college, higher*first_gen_college.

```
activelm <- lm(G3 ~ (sex + schoolsup + romantic + freetime + goout + absences + failed + Mjob + studytir

summary(activelm)
```

```
##
## Call:
## lm(formula = G3 ~ (sex + schoolsup + romantic + freetime + goout +
##     absences + failed + Mjob + studytime + higher + first_gen_college +
##     famsup)^2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.6429  -1.7534   0.2846   2.2075   7.3177
##
## Coefficients: (2 not defined because of singularities)
##                                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)                       -1.506826  13.118897  -0.115 0.908638
## sexM                               0.892073   5.622189   0.159 0.874042
## schoolsupyes                      13.761155   9.218122   1.493 0.136598
## romanticyes                       -1.449784   4.692335  -0.309 0.757574
## freetimelow                        2.630885   4.451459   0.591 0.554983
## gooutlow                          -1.031107  10.156300  -0.102 0.919207
## absences                           0.148759   0.316984   0.469 0.639221
## failedyes                         -8.234032   4.894235  -1.682 0.093599 .
## Mjobhealth                        -1.259093   5.227716  -0.241 0.809847
## Mjobother                         -5.143290   9.033916  -0.569 0.569585
## Mjobservices                       1.528706  11.532458   0.133 0.894638
## Mjobteacher                       -9.988699   6.801967  -1.469 0.143083
## studytime                          5.357552   4.658888   1.150 0.251133
## higheryes                         15.703850  12.568400   1.249 0.212529
## first_gen_collegeyes              -2.042557   2.769453  -0.738 0.461413
## famsupyes                         -1.124951   5.956632  -0.189 0.850341
## sexM:schoolsupyes                 -3.306582   1.597411  -2.070 0.039366 *
## sexM:romanticyes                   1.516326   1.076859   1.408 0.160203
## sexM:freetimelow                   0.440768   1.021810   0.431 0.666536
```

```
## sexM:gooutlow                        0.140986   1.100729   0.128 0.898174
## sexM:absences                       -0.168685   0.101499  -1.662 0.097636 .
## sexM:failedyes                      -0.812131   1.739573  -0.467 0.640963
## sexM:Mjobhealth                      4.072742   2.744648   1.484 0.138956
## sexM:Mjobother                       2.715976   1.700434   1.597 0.111336
## sexM:Mjobservices                    3.912599   1.832894   2.135 0.033651 *
## sexM:Mjobteacher                     4.222718   2.177167   1.940 0.053432 .
## sexM:studytime                      -0.342144   0.612314  -0.559 0.576761
## sexM:higheryes                      -4.325565   5.196762  -0.832 0.405911
## sexM:first_gen_collegeyes            3.448751   1.258091   2.741 0.006511 **
## sexM:famsupyes                       1.181025   1.031439   1.145 0.253169
## schoolsupyes:romanticyes             1.976315   1.776126   1.113 0.266780
## schoolsupyes:freetimelow             1.219474   1.826300   0.668 0.504853
## schoolsupyes:gooutlow               -0.008335   1.789930  -0.005 0.996288
## schoolsupyes:absences               -0.181005   0.097024  -1.866 0.063140 .
## schoolsupyes:failedyes               2.056166   1.959551   1.049 0.294936
## schoolsupyes:Mjobhealth             -2.452853   4.078269  -0.601 0.548027
## schoolsupyes:Mjobother              -0.957822   2.166765  -0.442 0.658791
## schoolsupyes:Mjobservices            0.062923   2.350522   0.027 0.978662
## schoolsupyes:Mjobteacher             3.535611   3.934416   0.899 0.369613
## schoolsupyes:studytime              -2.615114   0.957261  -2.732 0.006695 **
## schoolsupyes:higheryes             -11.448554   8.737679  -1.310 0.191177
## schoolsupyes:first_gen_collegeyes    5.330960   1.715583   3.107 0.002080 **
## schoolsupyes:famsupyes              -1.051195   1.608959  -0.653 0.514070
## romanticyes:freetimelow             -0.104303   1.110758  -0.094 0.925253
## romanticyes:gooutlow                -0.993412   1.145600  -0.867 0.386595
## romanticyes:absences                -0.067529   0.077543  -0.871 0.384569
## romanticyes:failedyes                1.610302   1.391467   1.157 0.248142
## romanticyes:Mjobhealth              -0.122641   2.593575  -0.047 0.962318
## romanticyes:Mjobother               -0.060667   1.643023  -0.037 0.970572
## romanticyes:Mjobservices            -1.237220   1.700337  -0.728 0.467443
## romanticyes:Mjobteacher              0.882332   2.215259   0.398 0.690712
## romanticyes:studytime               -0.687214   0.691971  -0.993 0.321500
## romanticyes:higheryes                2.788889   3.990571   0.699 0.485209
## romanticyes:first_gen_collegeyes     0.458349   1.253016   0.366 0.714791
## romanticyes:famsupyes               -0.577383   1.077682  -0.536 0.592544
## freetimelow:gooutlow                -0.941444   1.057541  -0.890 0.374107
## freetimelow:absences                 0.111240   0.091142   1.221 0.223287
## freetimelow:failedyes               -2.274094   1.541957  -1.475 0.141379
## freetimelow:Mjobhealth              -1.322847   2.588477  -0.511 0.609714
## freetimelow:Mjobother               -1.531530   1.864238  -0.822 0.412038
## freetimelow:Mjobservices            -0.462435   1.972455  -0.234 0.814808
## freetimelow:Mjobteacher             -1.231910   2.244147  -0.549 0.583479
## freetimelow:studytime                0.604095   0.669282   0.903 0.367508
## freetimelow:higheryes               -2.919575   3.673405  -0.795 0.427406
## freetimelow:first_gen_collegeyes     0.854057   1.330632   0.642 0.521496
## freetimelow:famsupyes               -1.330642   1.077589  -1.235 0.217921
## gooutlow:absences                   -0.049939   0.089046  -0.561 0.575366
## gooutlow:failedyes                  -0.174341   1.370430  -0.127 0.898860
## gooutlow:Mjobhealth                  1.457008   2.348034   0.621 0.535415
## gooutlow:Mjobother                  -0.418606   1.709665  -0.245 0.806753
## gooutlow:Mjobservices                0.912677   1.784840   0.511 0.609506
## gooutlow:Mjobteacher                 2.080526   2.307532   0.902 0.368026
## gooutlow:studytime                   1.127611   0.699657   1.612 0.108154
```

```
## gooutlow:higheryes                -0.372584   9.920550  -0.038 0.970068
## gooutlow:first_gen_collegeyes      1.024237   1.296276   0.790 0.430111
## gooutlow:famsupyes                -0.093945   1.093377  -0.086 0.931590
## absences:failedyes                 0.289277   0.073870   3.916 0.000113 ***
## absences:Mjobhealth               -0.044829   0.244754  -0.183 0.854806
## absences:Mjobother                -0.139807   0.139956  -0.999 0.318683
## absences:Mjobservices             -0.080993   0.153141  -0.529 0.597307
## absences:Mjobteacher              -0.105356   0.196984  -0.535 0.593178
## absences:studytime                 0.017934   0.057633   0.311 0.755901
## absences:higheryes                -0.102366   0.248758  -0.412 0.681012
## absences:first_gen_collegeyes      0.066378   0.098061   0.677 0.499021
## absences:famsupyes                 0.068059   0.073031   0.932 0.352175
## failedyes:Mjobhealth               3.888284   2.901794   1.340 0.181337
## failedyes:Mjobother               -1.029702   2.006996  -0.513 0.608314
## failedyes:Mjobservices             1.625498   2.056012   0.791 0.429838
## failedyes:Mjobteacher             -0.667717   4.128115  -0.162 0.871620
## failedyes:studytime                0.274374   0.971061   0.283 0.777729
## failedyes:higheryes               -1.349987   4.152803  -0.325 0.745363
## failedyes:first_gen_collegeyes     4.246604   1.838110   2.310 0.021593 *
## failedyes:famsupyes                0.068774   1.322558   0.052 0.958565
## Mjobhealth:studytime               2.929895   1.371083   2.137 0.033465 *
## Mjobother:studytime                0.867948   0.899516   0.965 0.335419
## Mjobservices:studytime             0.977495   0.967555   1.010 0.313230
## Mjobteacher:studytime              0.783722   1.376670   0.569 0.569614
## Mjobhealth:higheryes                    NA         NA      NA       NA
## Mjobother:higheryes                8.361265   8.588696   0.974 0.331129
## Mjobservices:higheryes             1.376403  11.159423   0.123 0.901926
## Mjobteacher:higheryes             10.776012   5.658085   1.905 0.057858 .
## Mjobhealth:first_gen_collegeyes   -5.333834   2.483592  -2.148 0.032595 *
## Mjobother:first_gen_collegeyes    -3.997660   1.895764  -2.109 0.035849 *
## Mjobservices:first_gen_collegeyes -5.602517   1.941616  -2.885 0.004210 **
## Mjobteacher:first_gen_collegeyes  -1.139043   3.603667  -0.316 0.752176
## Mjobhealth:famsupyes              -0.971463   2.603701  -0.373 0.709348
## Mjobother:famsupyes                0.228631   1.502886   0.152 0.879195
## Mjobservices:famsupyes            -0.129235   1.643959  -0.079 0.937397
## Mjobteacher:famsupyes             -1.875211   2.166962  -0.865 0.387575
## studytime:higheryes               -7.929807   4.479400  -1.770 0.077760 .
## studytime:first_gen_collegeyes     0.748786   0.744561   1.006 0.315434
## studytime:famsupyes                1.418357   0.614634   2.308 0.021743 *
## higheryes:first_gen_collegeyes           NA         NA      NA       NA
## higheryes:famsupyes               -1.524942   5.664120  -0.269 0.787951
## first_gen_collegeyes:famsupyes    -1.101570   1.255553  -0.877 0.381039
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.84 on 282 degrees of freedom
## Multiple R-squared:  0.4973, Adjusted R-squared:  0.2976
## F-statistic: 2.491 on 112 and 282 DF,  p-value: 5.445e-10
```

From this, we can see that there seem to be significant interaction effects between sex and schoolsup, sex and first_gen_college, sex and Mjob, schoolsup and absences, schoolsup and studytime, schoolsup and first_gen_college, absences and failed, failed and first_gen_college, Mjob and studytime, Mjob and first_gen_college, studytime and famsup.

### Linear model on the training data set

```
base_lm_tr <- lm(G3 ~ . -G2 -G1 -ord_g3 -stable_learning_env, data = training)
step.model_tr <- stepAIC(base_lm_tr, direction="both")
```

```
## Start:  AIC=927.72
## G3 ~ (school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + Fjob + reason + guardian + traveltime + studytime +
##     failures + schoolsup + famsup + paid + activities + nursery +
##     higher + internet + romantic + famrel + freetime + goout +
##     Dalc + Walc + health + absences + G1 + G2 + first_gen_college +
##     stable_learning_env + high_freq_absent + failed + ord_g3) -
##     G2 - G1 - ord_g3 - stable_learning_env
##
##                      Df Sum of Sq    RSS    AIC
## - Fjob                4    25.052 4559.3 921.46
## - guardian            2     3.373 4537.6 923.96
## - reason              3    50.313 4584.6 925.21
## - higher              1     0.036 4534.3 925.72
## - Walc                1     0.204 4534.5 925.73
## - Dalc                1     0.358 4534.6 925.75
## - famrel              1     0.371 4534.6 925.75
## - Medu                1     0.921 4535.2 925.78
## - Fedu                1     5.124 4539.4 926.08
## - nursery             1     5.172 4539.4 926.08
## - high_freq_absent    1     7.005 4541.3 926.21
## - activities          1     7.286 4541.5 926.23
## - address             1    11.194 4545.4 926.50
## - internet            1    12.933 4547.2 926.62
## - traveltime          1    17.745 4552.0 926.95
## - failures            1    18.130 4552.4 926.98
## - Pstatus             1    19.946 4554.2 927.11
## - health              1    26.319 4560.6 927.55
## <none>                            4534.3 927.72
## - school              1    30.003 4564.3 927.80
## - paid                1    34.856 4569.1 928.14
## - first_gen_college   1    37.337 4571.6 928.31
## - studytime           1    55.699 4589.9 929.58
## - failed              1    56.947 4591.2 929.66
## - Mjob                4   145.059 4679.3 929.67
## - schoolsup           1    67.383 4601.6 930.38
## - famsize             1    68.749 4603.0 930.48
## - age                 1    69.869 4604.1 930.55
## - absences            1    81.239 4615.5 931.33
## - famsup              1    81.674 4615.9 931.36
## - sex                 1    89.555 4623.8 931.90
## - romantic            1   110.934 4645.2 933.36
## - goout               1   127.344 4661.6 934.47
## - freetime            1   135.158 4669.4 935.00
##
## Step:  AIC=921.46
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + reason + guardian + traveltime + studytime +
##     failures + schoolsup + famsup + paid + activities + nursery +
```

```
##     higher + internet + romantic + famrel + freetime + goout +
##     Dalc + Walc + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                      Df Sum of Sq    RSS    AIC
## - guardian            2     2.456 4561.8 917.63
## - reason              3    54.677 4614.0 919.23
## - higher              1     0.001 4559.3 919.46
## - Dalc                1     0.003 4559.3 919.46
## - famrel              1     0.064 4559.4 919.47
## - Medu                1     1.476 4560.8 919.56
## - Fedu                1     2.289 4561.6 919.62
## - Walc                1     2.340 4561.6 919.62
## - nursery             1     5.992 4565.3 919.88
## - activities          1     7.690 4567.0 919.99
## - high_freq_absent    1     9.336 4568.6 920.11
## - internet            1    11.909 4571.2 920.29
## - address             1    12.789 4572.1 920.35
## - traveltime          1    14.191 4573.5 920.44
## - failures            1    17.216 4576.5 920.65
## - Pstatus             1    22.362 4581.7 921.01
## - paid                1    26.525 4585.8 921.29
## - health              1    27.034 4586.3 921.33
## <none>                           4559.3 921.46
## - school              1    30.178 4589.5 921.55
## - first_gen_college   1    41.045 4600.3 922.29
## - Mjob                4   142.087 4701.4 923.16
## - studytime           1    55.029 4614.3 923.25
## - failed              1    56.172 4615.5 923.33
## - famsize             1    62.299 4621.6 923.75
## - schoolsup           1    65.516 4624.8 923.97
## - age                 1    67.063 4626.4 924.08
## - famsup              1    85.588 4644.9 925.34
## - absences            1    88.683 4648.0 925.55
## - sex                 1    92.448 4651.8 925.81
## - romantic            1   109.267 4668.6 926.95
## + Fjob                4    25.052 4534.3 927.72
## - goout               1   122.960 4682.3 927.87
## - freetime            1   140.161 4699.5 929.03
##
## Step:  AIC=917.63
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + reason + traveltime + studytime + failures +
##     schoolsup + famsup + paid + activities + nursery + higher +
##     internet + romantic + famrel + freetime + goout + Dalc +
##     Walc + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                      Df Sum of Sq    RSS    AIC
## - reason              3    56.461 4618.2 915.52
## - Dalc                1     0.005 4561.8 915.63
## - higher              1     0.035 4561.8 915.63
## - famrel              1     0.062 4561.8 915.64
## - Medu                1     1.075 4562.8 915.71
```

```
## - Fedu               1     1.599 4563.4 915.74
## - Walc               1     2.545 4564.3 915.81
## - nursery            1     7.566 4569.3 916.16
## - activities         1     7.927 4569.7 916.18
## - high_freq_absent   1     9.108 4570.9 916.26
## - internet           1    11.546 4573.3 916.43
## - traveltime         1    12.455 4574.2 916.49
## - address            1    15.272 4577.0 916.69
## - failures           1    17.008 4578.8 916.81
## - Pstatus            1    23.387 4585.1 917.25
## - paid               1    27.112 4588.9 917.50
## <none>                           4561.8 917.63
## - health             1    29.203 4591.0 917.65
## - school             1    29.267 4591.0 917.65
## - first_gen_college  1    40.635 4602.4 918.43
## - failed             1    54.354 4616.1 919.37
## - Mjob               4   143.807 4705.6 919.44
## - studytime          1    57.318 4619.1 919.58
## - famsize            1    61.877 4623.6 919.89
## - schoolsup          1    64.734 4626.5 920.08
## - age                1    68.830 4630.6 920.36
## - famsup             1    84.566 4646.3 921.44
## + guardian           2     2.456 4559.3 921.46
## - absences           1    88.161 4649.9 921.68
## - sex                1    93.058 4654.8 922.01
## - romantic           1   110.186 4671.9 923.17
## + Fjob               4    24.135 4537.6 923.96
## - goout              1   132.764 4694.5 924.70
## - freetime           1   149.181 4710.9 925.80
##
## Step:  AIC=915.52
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
##     famsup + paid + activities + nursery + higher + internet +
##     romantic + famrel + freetime + goout + Dalc + Walc + health +
##     absences + first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - higher             1     0.000 4618.2 913.52
## - Dalc               1     0.197 4618.4 913.53
## - famrel             1     0.440 4618.7 913.55
## - Fedu               1     2.425 4620.6 913.68
## - Walc               1     3.203 4621.4 913.74
## - Medu               1     3.626 4621.8 913.77
## - activities         1     3.649 4621.9 913.77
## - nursery            1     5.593 4623.8 913.90
## - high_freq_absent   1     6.845 4625.1 913.99
## - address            1     9.786 4628.0 914.19
## - internet           1    11.003 4629.2 914.27
## - traveltime         1    15.053 4633.3 914.55
## - Pstatus            1    22.545 4640.8 915.06
## - failures           1    22.829 4641.0 915.08
## - school             1    26.310 4644.5 915.31
## <none>                           4618.2 915.52
```

```
## - first_gen_college  1    36.895 4655.1 916.03
## - paid               1    37.204 4655.4 916.05
## - health             1    41.384 4659.6 916.34
## - failed             1    46.596 4664.8 916.69
## - studytime          1    57.716 4675.9 917.44
## + reason             3    56.461 4561.8 917.63
## - schoolsup          1    64.672 4682.9 917.91
## - famsize            1    64.838 4683.1 917.92
## - age                1    67.842 4686.1 918.13
## - Mjob               4   158.447 4776.7 918.18
## + guardian           2     4.240 4614.0 919.23
## - famsup             1    84.960 4703.2 919.28
## - sex                1    85.096 4703.3 919.29
## - absences           1    93.470 4711.7 919.85
## - romantic           1   105.080 4723.3 920.63
## + Fjob               4    28.845 4589.4 921.54
## - goout              1   137.376 4755.6 922.78
## - freetime           1   146.968 4765.2 923.42
##
## Step:  AIC=913.52
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
##     famsup + paid + activities + nursery + internet + romantic +
##     famrel + freetime + goout + Dalc + Walc + health + absences +
##     first_gen_college + high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - Dalc               1     0.196 4618.4 911.53
## - famrel             1     0.439 4618.7 911.55
## - Fedu               1     2.451 4620.7 911.69
## - Walc               1     3.207 4621.4 911.74
## - Medu               1     3.628 4621.8 911.77
## - activities         1     3.662 4621.9 911.77
## - nursery            1     5.593 4623.8 911.90
## - high_freq_absent   1     6.942 4625.2 911.99
## - address            1     9.786 4628.0 912.19
## - internet           1    11.037 4629.3 912.27
## - traveltime         1    15.075 4633.3 912.55
## - Pstatus            1    22.556 4640.8 913.06
## - failures           1    23.561 4641.8 913.13
## - school             1    26.483 4644.7 913.33
## <none>                           4618.2 913.52
## - first_gen_college  1    36.895 4655.1 914.03
## - paid               1    37.615 4655.8 914.08
## - health             1    41.386 4659.6 914.34
## - failed             1    46.981 4665.2 914.72
## - studytime          1    58.310 4676.5 915.48
## + higher             1     0.000 4618.2 915.52
## + reason             3    56.425 4561.8 915.63
## - schoolsup          1    64.687 4682.9 915.91
## - famsize            1    64.840 4683.1 915.92
## - Mjob               4   158.597 4776.8 916.19
## - age                1    69.331 4687.6 916.23
## + guardian           2     4.201 4614.0 917.23
```

```
## - famsup             1    85.007 4703.2 917.28
## - sex                1    86.601 4704.8 917.39
## - absences           1    94.813 4713.0 917.94
## - romantic           1   106.608 4724.8 918.73
## + Fjob               4    28.844 4589.4 919.54
## - goout              1   137.383 4755.6 920.78
## - freetime           1   146.990 4765.2 921.42
##
## Step:  AIC=911.53
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
##     famsup + paid + activities + nursery + internet + romantic +
##     famrel + freetime + goout + Walc + health + absences + first_gen_college +
##     high_freq_absent + failed
##
##                     Df Sum of Sq    RSS    AIC
## - famrel             1     0.467 4618.9 909.56
## - Fedu               1     2.410 4620.8 909.70
## - Walc               1     3.018 4621.4 909.74
## - activities         1     3.619 4622.0 909.78
## - Medu               1     3.662 4622.1 909.78
## - nursery            1     6.145 4624.6 909.95
## - high_freq_absent   1     6.746 4625.2 909.99
## - address            1    10.060 4628.5 910.22
## - internet           1    11.105 4629.5 910.29
## - traveltime         1    14.931 4633.3 910.55
## - Pstatus            1    23.051 4641.5 911.11
## - failures           1    23.421 4641.8 911.13
## - school             1    26.986 4645.4 911.37
## <none>                           4618.4 911.53
## - first_gen_college  1    36.800 4655.2 912.04
## - paid               1    38.982 4657.4 912.19
## - health             1    41.199 4659.6 912.34
## - failed             1    47.590 4666.0 912.77
## - studytime          1    58.437 4676.9 913.51
## + Dalc               1     0.196 4618.2 913.52
## + higher             1     0.000 4618.4 913.53
## + reason             3    56.616 4561.8 913.63
## - schoolsup          1    64.538 4683.0 913.92
## - famsize            1    65.013 4683.4 913.95
## - Mjob               4   158.749 4777.2 914.21
## - age                1    69.138 4687.6 914.23
## + guardian           2     4.233 4614.2 915.24
## - famsup             1    85.027 4703.4 915.30
## - sex                1    87.210 4705.6 915.44
## - absences           1    94.843 4713.3 915.96
## - romantic           1   106.605 4725.0 916.74
## + Fjob               4    28.899 4589.5 917.55
## - goout              1   137.482 4755.9 918.80
## - freetime           1   148.808 4767.2 919.55
##
## Step:  AIC=909.56
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Fedu + Mjob + traveltime + studytime + failures + schoolsup +
```

```
##     famsup + paid + activities + nursery + internet + romantic +
##     freetime + goout + Walc + health + absences + first_gen_college +
##     high_freq_absent + failed
##
##                      Df Sum of Sq    RSS    AIC
## - Fedu                1     2.288 4621.2 907.72
## - Walc                1     3.540 4622.4 907.81
## - activities          1     3.632 4622.5 907.81
## - Medu                1     3.758 4622.6 907.82
## - nursery             1     6.014 4624.9 907.98
## - high_freq_absent    1     7.094 4626.0 908.05
## - address             1    10.211 4629.1 908.26
## - internet            1    11.223 4630.1 908.33
## - traveltime          1    14.719 4633.6 908.57
## - Pstatus             1    22.801 4641.7 909.12
## - failures            1    23.858 4642.7 909.19
## - school              1    26.528 4645.4 909.37
## <none>                           4618.9 909.56
## - first_gen_college   1    36.728 4655.6 910.07
## - paid                1    39.415 4658.3 910.25
## - health              1    40.797 4659.7 910.34
## - failed              1    47.519 4666.4 910.80
## + famrel              1     0.467 4618.4 911.53
## + Dalc                1     0.224 4618.7 911.55
## - studytime           1    58.712 4677.6 911.56
## + higher              1     0.000 4618.9 911.56
## + reason              3    57.019 4561.9 911.64
## - schoolsup           1    64.366 4683.2 911.94
## - famsize             1    65.123 4684.0 911.99
## - age                 1    68.765 4687.6 912.23
## - Mjob                4   159.308 4778.2 912.28
## + guardian            2     4.154 4614.7 913.28
## - famsup              1    84.826 4703.7 913.32
## - sex                 1    88.733 4707.6 913.58
## - absences            1    95.626 4714.5 914.04
## - romantic            1   106.423 4725.3 914.76
## + Fjob                4    28.327 4590.6 915.62
## - goout               1   137.094 4756.0 916.81
## - freetime            1   153.451 4772.3 917.89
##
## Step:  AIC=907.72
## G3 ~ school + sex + age + address + famsize + Pstatus + Medu +
##     Mjob + traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + nursery + internet + romantic + freetime +
##     goout + Walc + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                      Df Sum of Sq    RSS    AIC
## - Medu                1     2.716 4623.9 905.91
## - Walc                1     3.732 4624.9 905.98
## - activities          1     3.937 4625.1 905.99
## - high_freq_absent    1     6.461 4627.6 906.16
## - nursery             1     6.563 4627.7 906.17
## - address             1    10.636 4631.8 906.45
```

```
## - internet           1    11.233 4632.4 906.49
## - traveltime         1    13.638 4634.8 906.65
## - Pstatus            1    22.105 4643.3 907.23
## - failures           1    22.136 4643.3 907.23
## - school             1    25.743 4646.9 907.48
## <none>                           4621.2 907.72
## - first_gen_college  1    36.511 4657.7 908.21
## - paid               1    40.059 4661.2 908.45
## - health             1    41.096 4662.3 908.52
## - failed             1    49.573 4670.7 909.09
## + Fedu               1     2.288 4618.9 909.56
## + famrel             1     0.345 4620.8 909.70
## + Dalc               1     0.178 4621.0 909.71
## + higher             1     0.022 4621.1 909.72
## + reason             3    57.777 4563.4 909.75
## - studytime          1    62.725 4683.9 909.98
## - famsize            1    65.935 4687.1 910.20
## - schoolsup          1    66.605 4687.8 910.24
## - Mjob               4   157.259 4778.4 910.30
## - age                1    69.879 4691.1 910.46
## + guardian           2     2.871 4618.3 911.52
## - sex                1    87.997 4709.2 911.68
## - famsup             1    89.835 4711.0 911.81
## - absences           1    94.024 4715.2 912.09
## - romantic           1   106.822 4728.0 912.94
## + Fjob               4    24.289 4596.9 914.06
## - goout              1   138.827 4760.0 915.07
## - freetime           1   158.481 4779.7 916.38
##
## Step:  AIC=905.91
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + nursery + internet + romantic + freetime +
##     goout + Walc + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## - Walc               1     3.904 4627.8 904.17
## - activities         1     4.142 4628.0 904.19
## - high_freq_absent   1     5.900 4629.8 904.31
## - nursery            1     6.240 4630.1 904.33
## - address            1    11.026 4634.9 904.66
## - internet           1    11.360 4635.2 904.68
## - traveltime         1    14.136 4638.0 904.87
## - failures           1    22.039 4645.9 905.41
## - Pstatus            1    23.280 4647.2 905.49
## - school             1    25.026 4648.9 905.61
## <none>                           4623.9 905.91
## - paid               1    40.304 4664.2 906.65
## - health             1    44.173 4668.1 906.91
## - failed             1    51.557 4675.4 907.41
## + Medu               1     2.716 4621.2 907.72
## + reason             3    59.868 4564.0 907.79
## + Fedu               1     1.247 4622.6 907.82
```

```
## + famrel             1     0.446 4623.4 907.88
## + Dalc               1     0.221 4623.7 907.89
## + higher             1     0.020 4623.9 907.91
## - famsize            1    63.719 4687.6 908.23
## - studytime          1    66.557 4690.4 908.42
## - schoolsup          1    67.735 4691.6 908.50
## - age                1    70.228 4694.1 908.67
## - Mjob               4   160.854 4784.7 908.71
## - first_gen_college  1    80.781 4704.7 909.38
## + guardian           2     2.473 4621.4 909.74
## - famsup             1    87.926 4711.8 909.86
## - sex                1    91.639 4715.5 910.11
## - absences           1    98.034 4721.9 910.54
## - romantic           1   105.730 4729.6 911.05
## + Fjob               4    25.623 4598.3 912.15
## - goout              1   136.934 4760.8 913.13
## - freetime           1   157.319 4781.2 914.48
##
## Step:  AIC=904.17
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + activities + nursery + internet + romantic + freetime +
##     goout + health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## - activities         1     4.178 4632.0 902.46
## - nursery            1     5.015 4632.8 902.52
## - high_freq_absent   1     7.291 4635.1 902.67
## - address            1    11.211 4639.0 902.94
## - internet           1    11.897 4639.7 902.98
## - traveltime         1    15.286 4643.1 903.22
## - Pstatus            1    22.412 4650.2 903.70
## - failures           1    23.632 4651.4 903.78
## - school             1    25.623 4653.4 903.92
## <none>                           4627.8 904.17
## - paid               1    39.528 4667.3 904.86
## - health             1    47.178 4675.0 905.38
## - failed             1    50.269 4678.1 905.59
## + Walc               1     3.904 4623.9 905.91
## + Medu               1     2.888 4624.9 905.98
## + reason             3    60.583 4567.2 906.01
## + Fedu               1     1.364 4626.4 906.08
## + famrel             1     0.987 4626.8 906.11
## + Dalc               1     0.015 4627.8 906.17
## + higher             1     0.003 4627.8 906.17
## - famsize            1    62.702 4690.5 906.43
## - schoolsup          1    67.153 4694.9 906.73
## - studytime          1    67.748 4695.5 906.77
## - age                1    67.910 4695.7 906.78
## - Mjob               4   162.533 4790.3 907.08
## - first_gen_college  1    79.320 4707.1 907.54
## - famsup             1    85.618 4713.4 907.97
## + guardian           2     2.682 4625.1 907.99
```

```
## - sex                1    87.930 4715.7 908.12
## - absences           1    96.725 4724.5 908.71
## - romantic           1   105.538 4733.3 909.30
## + Fjob               4    27.949 4599.8 910.26
## - freetime           1   161.494 4789.3 913.01
## - goout              1   189.734 4817.5 914.87
##
## Step:  AIC=902.46
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + nursery + internet + romantic + freetime + goout +
##     health + absences + first_gen_college + high_freq_absent +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## - nursery            1     5.067 4637.0 900.80
## - high_freq_absent   1     6.862 4638.8 900.93
## - internet           1    11.689 4643.7 901.25
## - address            1    12.273 4644.2 901.29
## - traveltime         1    14.998 4647.0 901.48
## - failures           1    22.502 4654.5 901.99
## - Pstatus            1    24.454 4656.4 902.12
## - school             1    27.167 4659.1 902.31
## <none>                           4632.0 902.46
## - paid               1    40.599 4672.6 903.22
## - health             1    47.606 4679.6 903.69
## - failed             1    52.022 4684.0 903.99
## + activities         1     4.178 4627.8 904.17
## + Walc               1     3.940 4628.0 904.19
## + Medu               1     3.101 4628.9 904.25
## + Fedu               1     1.572 4630.4 904.35
## + famrel             1     1.003 4631.0 904.39
## + Dalc               1     0.032 4631.9 904.46
## + higher             1     0.028 4631.9 904.46
## + reason             3    56.135 4575.8 904.61
## - famsize            1    63.140 4695.1 904.74
## - studytime          1    65.022 4697.0 904.86
## - age                1    66.050 4698.0 904.93
## - schoolsup          1    67.088 4699.1 905.00
## - Mjob               4   164.263 4796.2 905.47
## - first_gen_college  1    77.150 4709.1 905.68
## - famsup             1    85.006 4717.0 906.21
## - sex                1    85.140 4717.1 906.21
## + guardian           2     2.670 4629.3 906.28
## - absences           1    95.919 4727.9 906.94
## - romantic           1   107.519 4739.5 907.71
## + Fjob               4    28.113 4603.9 908.53
## - freetime           1   159.222 4791.2 911.14
## - goout              1   192.427 4824.4 913.32
##
## Step:  AIC=900.8
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + internet + romantic + freetime + goout + health +
```

```
##     absences + first_gen_college + high_freq_absent + failed
##
##                      Df Sum of Sq    RSS    AIC
## - high_freq_absent    1     7.525 4644.6 899.32
## - address             1    11.795 4648.8 899.61
## - internet            1    12.829 4649.9 899.68
## - traveltime          1    15.140 4652.2 899.83
## - failures            1    22.776 4659.8 900.35
## - Pstatus             1    23.686 4660.7 900.41
## - school              1    28.953 4666.0 900.77
## <none>                            4637.0 900.80
## - paid                1    38.795 4675.8 901.44
## - health              1    47.660 4684.7 902.04
## - failed              1    51.399 4688.4 902.29
## + nursery             1     5.067 4632.0 902.46
## + activities          1     4.230 4632.8 902.52
## + Medu                1     2.757 4634.3 902.62
## + Walc                1     2.704 4634.3 902.62
## + Fedu                1     2.000 4635.0 902.67
## + famrel              1     0.699 4636.3 902.76
## + Dalc                1     0.077 4637.0 902.80
## + higher              1     0.025 4637.0 902.80
## - famsize             1    60.239 4697.3 902.88
## - studytime           1    62.151 4699.2 903.01
## + reason              3    54.246 4582.8 903.09
## - age                 1    64.954 4702.0 903.20
## - schoolsup           1    68.628 4705.7 903.45
## - Mjob                4   162.543 4799.6 903.69
## - first_gen_college   1    74.036 4711.1 903.81
## - famsup              1    83.040 4720.1 904.41
## - sex                 1    84.148 4721.2 904.49
## + guardian            2     3.830 4633.2 904.54
## - absences            1    97.372 4734.4 905.37
## - romantic            1   107.431 4744.5 906.04
## + Fjob                4    28.374 4608.7 906.86
## - freetime            1   163.247 4800.3 909.74
## - goout               1   194.154 4831.2 911.77
##
## Step:  AIC=899.32
## G3 ~ school + sex + age + address + famsize + Pstatus + Mjob +
##     traveltime + studytime + failures + schoolsup + famsup +
##     paid + internet + romantic + freetime + goout + health +
##     absences + first_gen_college + failed
##
##                      Df Sum of Sq    RSS    AIC
## - address             1    10.888 4655.4 898.06
## - internet            1    12.243 4656.8 898.15
## - traveltime          1    13.276 4657.8 898.22
## - failures            1    22.376 4666.9 898.84
## - Pstatus             1    22.751 4667.3 898.86
## - school              1    29.054 4673.6 899.29
## <none>                            4644.6 899.32
## - paid                1    38.496 4683.1 899.92
## - health              1    45.625 4690.2 900.41
```

```
## + high_freq_absent   1     7.525 4637.0 900.80
## + nursery            1     5.730 4638.8 900.93
## - failed             1    53.561 4698.1 900.94
## + Walc               1     3.825 4640.7 901.06
## + activities         1     3.782 4640.8 901.06
## + Medu               1     2.117 4642.4 901.17
## - famsize            1    57.573 4702.1 901.21
## + Fedu               1     1.525 4643.0 901.21
## + famrel             1     1.236 4643.3 901.23
## + higher             1     0.191 4644.4 901.30
## + Dalc               1     0.053 4644.5 901.31
## - studytime          1    64.806 4709.4 901.70
## + reason             3    51.488 4593.1 901.79
## - schoolsup          1    66.391 4711.0 901.80
## - age                1    67.062 4711.6 901.85
## - Mjob               4   159.553 4804.1 901.99
## - first_gen_college  1    70.839 4715.4 902.10
## - sex                1    83.878 4728.4 902.97
## + guardian           2     3.663 4640.9 903.07
## - famsup             1    85.915 4730.5 903.11
## - romantic           1   107.706 4752.3 904.56
## + Fjob               4    30.169 4614.4 905.26
## - absences           1   122.998 4767.6 905.58
## - freetime           1   159.558 4804.1 907.99
## - goout              1   198.114 4842.7 910.52
##
## Step:  AIC=898.06
## G3 ~ school + sex + age + famsize + Pstatus + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + paid + internet +
##     romantic + freetime + goout + health + absences + first_gen_college +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## - internet           1    17.076 4672.5 897.21
## - traveltime         1    22.097 4677.5 897.55
## - failures           1    22.963 4678.4 897.61
## - school             1    23.121 4678.6 897.62
## - Pstatus            1    23.721 4679.2 897.66
## <none>                           4655.4 898.06
## - paid               1    38.359 4693.8 898.65
## + address            1    10.888 4644.6 899.32
## - health             1    48.864 4704.3 899.36
## + high_freq_absent   1     6.618 4648.8 899.61
## + nursery            1     5.198 4650.3 899.70
## - failed             1    54.289 4709.7 899.72
## + activities         1     4.759 4650.7 899.73
## + Walc               1     3.988 4651.5 899.79
## + Medu               1     2.539 4652.9 899.88
## + Fedu               1     1.844 4653.6 899.93
## + famrel             1     1.469 4654.0 899.96
## + higher             1     0.188 4655.3 900.04
## + Dalc               1     0.000 4655.4 900.06
## - studytime          1    59.649 4715.1 900.08
## - famsize            1    60.883 4716.3 900.16
```

```
## - age                1    67.556 4723.0 900.61
## - schoolsup          1    67.754 4723.2 900.62
## - first_gen_college  1    69.505 4725.0 900.74
## + reason             3    46.296 4609.2 900.90
## - Mjob               4   163.441 4818.9 900.96
## - sex                1    80.414 4735.9 901.47
## + guardian           2     5.868 4649.6 901.66
## - famsup             1    89.836 4745.3 902.10
## - romantic           1   107.007 4762.5 903.24
## + Fjob               4    31.716 4623.7 903.90
## - absences           1   118.305 4773.8 903.99
## - freetime           1   160.073 4815.5 906.74
## - goout              1   195.465 4850.9 909.05
##
## Step:  AIC=897.21
## G3 ~ school + sex + age + famsize + Pstatus + Mjob + traveltime +
##     studytime + failures + schoolsup + famsup + paid + romantic +
##     freetime + goout + health + absences + first_gen_college +
##     failed
##
##                     Df Sum of Sq    RSS    AIC
## - Pstatus            1    19.015 4691.5 896.50
## - school             1    21.569 4694.1 896.67
## - failures           1    21.788 4694.3 896.68
## - traveltime         1    23.853 4696.4 896.82
## <none>                           4672.5 897.21
## + internet           1    17.076 4655.4 898.06
## - paid               1    43.019 4715.5 898.11
## + address            1    15.721 4656.8 898.15
## - health             1    52.668 4725.2 898.76
## + nursery            1     6.408 4666.1 898.78
## + high_freq_absent   1     5.782 4666.7 898.82
## + activities         1     4.747 4667.8 898.89
## + Walc               1     4.446 4668.1 898.91
## + Medu               1     2.790 4669.7 899.02
## + Fedu               1     1.987 4670.5 899.08
## + famrel             1     1.765 4670.8 899.09
## - failed             1    58.055 4730.6 899.12
## + higher             1     0.379 4672.1 899.19
## + Dalc               1     0.031 4672.5 899.21
## - famsize            1    61.777 4734.3 899.36
## - studytime          1    61.937 4734.5 899.37
## - schoolsup          1    68.343 4740.9 899.80
## - first_gen_college  1    70.528 4743.1 899.95
## - age                1    72.763 4745.3 900.10
## + reason             3    45.034 4627.5 900.15
## - Mjob               4   168.611 4841.1 900.42
## - sex                1    82.535 4755.1 900.75
## + guardian           2     5.820 4666.7 900.82
## - famsup             1    86.871 4759.4 901.03
## - romantic           1    98.108 4770.6 901.78
## + Fjob               4    30.735 4641.8 903.13
## - absences           1   128.687 4801.2 903.80
## - freetime           1   155.787 4828.3 905.58
```

```
## - goout              1   194.404 4866.9 908.09
##
## Step:  AIC=896.5
## G3 ~ school + sex + age + famsize + Mjob + traveltime + studytime +
##     failures + schoolsup + famsup + paid + romantic + freetime +
##     goout + health + absences + first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## - school             1    20.534 4712.1 895.88
## - failures           1    20.551 4712.1 895.88
## - traveltime         1    26.808 4718.3 896.30
## <none>                           4691.5 896.50
## - paid               1    37.875 4729.4 897.04
## + Pstatus            1    19.015 4672.5 897.21
## + address            1    15.946 4675.6 897.42
## + internet           1    12.371 4679.2 897.66
## - health             1    50.727 4742.3 897.90
## + activities         1     6.716 4684.8 898.04
## + nursery            1     5.386 4686.2 898.13
## + high_freq_absent   1     5.106 4686.4 898.15
## + Medu               1     3.943 4687.6 898.23
## + Walc               1     3.552 4688.0 898.26
## + Fedu               1     1.258 4690.3 898.41
## + famrel             1     1.224 4690.3 898.41
## + Dalc               1     0.296 4691.2 898.48
## + higher             1     0.216 4691.3 898.48
## - failed             1    61.500 4753.0 898.61
## - studytime          1    62.139 4753.7 898.65
## - schoolsup          1    66.578 4758.1 898.95
## - famsize            1    71.246 4762.8 899.26
## - age                1    72.054 4763.6 899.31
## + reason             3    44.134 4647.4 899.51
## - sex                1    81.989 4773.5 899.97
## + guardian           2     6.841 4684.7 900.04
## - first_gen_college  1    83.323 4774.9 900.06
## - Mjob               4   175.278 4866.8 900.09
## - famsup             1    85.654 4777.2 900.21
## - romantic           1    97.402 4788.9 900.99
## + Fjob               4    32.692 4658.8 902.29
## - absences           1   140.967 4832.5 903.85
## - freetime           1   146.356 4837.9 904.20
## - goout              1   193.877 4885.4 907.29
##
## Step:  AIC=895.88
## G3 ~ sex + age + famsize + Mjob + traveltime + studytime + failures +
##     schoolsup + famsup + paid + romantic + freetime + goout +
##     health + absences + first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## - traveltime         1    17.052 4729.1 895.02
## - failures           1    23.556 4735.6 895.45
## <none>                           4712.1 895.88
## + school             1    20.534 4691.5 896.50
## - paid               1    39.965 4752.0 896.55
```

```
## + Pstatus            1    17.980 4694.1 896.67
## + internet           1    11.208 4700.9 897.12
## + address            1     8.647 4703.4 897.30
## + activities         1     7.951 4704.1 897.34
## + nursery            1     7.080 4705.0 897.40
## - age                1    54.142 4766.2 897.49
## + high_freq_absent   1     5.453 4706.6 897.51
## - health             1    54.765 4766.8 897.53
## - studytime          1    56.040 4768.1 897.61
## + Walc               1     3.855 4708.2 897.62
## + Medu               1     2.933 4709.1 897.68
## - failed             1    58.468 4770.5 897.77
## + Fedu               1     0.852 4711.2 897.82
## + Dalc               1     0.610 4711.5 897.84
## + famrel             1     0.320 4711.8 897.86
## + higher             1     0.003 4712.1 897.88
## - schoolsup          1    66.967 4779.0 898.34
## - famsize            1    72.499 4784.6 898.70
## - sex                1    77.262 4789.3 899.02
## + reason             3    41.679 4670.4 899.07
## - first_gen_college  1    81.934 4794.0 899.32
## - Mjob               4   174.514 4886.6 899.37
## + guardian           2     4.868 4707.2 899.55
## - romantic           1    94.621 4806.7 900.16
## - famsup             1    96.177 4808.3 900.26
## + Fjob               4    35.159 4676.9 901.51
## - absences           1   126.801 4838.9 902.27
## - freetime           1   154.525 4866.6 904.07
## - goout              1   202.366 4914.4 907.16
##
## Step:  AIC=895.02
## G3 ~ sex + age + famsize + Mjob + studytime + failures + schoolsup +
##     famsup + paid + romantic + freetime + goout + health + absences +
##     first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## - failures           1    24.582 4753.7 894.66
## <none>                           4729.1 895.02
## + Pstatus            1    20.570 4708.6 895.64
## + traveltime         1    17.052 4712.1 895.88
## + address            1    17.020 4712.1 895.88
## - paid               1    43.139 4772.3 895.89
## + internet           1    12.480 4716.6 896.18
## + school             1    10.778 4718.3 896.30
## + activities         1     7.906 4721.2 896.49
## + nursery            1     6.473 4722.7 896.59
## - age                1    54.411 4783.5 896.63
## - health             1    54.994 4784.1 896.67
## + Walc               1     4.849 4724.3 896.69
## + Medu               1     4.223 4724.9 896.74
## + high_freq_absent   1     3.219 4725.9 896.80
## - failed             1    58.351 4787.5 896.89
## + Dalc               1     0.382 4728.7 896.99
## + famrel             1     0.323 4728.8 897.00
```

```
## + Fedu               1     0.267 4728.9 897.00
## + higher             1     0.021 4729.1 897.02
## - studytime          1    60.228 4789.4 897.02
## - schoolsup          1    63.756 4792.9 897.25
## - famsize            1    68.825 4798.0 897.58
## - sex                1    75.532 4804.7 898.03
## + reason             3    43.987 4685.1 898.07
## - first_gen_college  1    82.183 4811.3 898.46
## + guardian           2     3.243 4725.9 898.80
## - famsup             1    99.775 4828.9 899.62
## - romantic           1   101.172 4830.3 899.71
## - Mjob               4   194.583 4923.7 899.76
## + Fjob               4    32.399 4696.7 900.85
## - absences           1   132.613 4861.7 901.76
## - freetime           1   158.505 4887.6 903.44
## - goout              1   210.307 4939.4 906.77
##
## Step:  AIC=894.66
## G3 ~ sex + age + famsize + Mjob + studytime + schoolsup + famsup +
##     paid + romantic + freetime + goout + health + absences +
##     first_gen_college + failed
##
##                     Df Sum of Sq    RSS    AIC
## <none>                           4753.7 894.66
## + failures           1     24.58 4729.1 895.02
## + Pstatus            1     19.17 4734.5 895.38
## + traveltime         1     18.08 4735.6 895.45
## + address            1     17.27 4736.4 895.51
## - paid               1     43.30 4797.0 895.52
## + school             1     12.75 4741.0 895.81
## + internet           1     11.52 4742.2 895.89
## - health             1     52.68 4806.4 896.14
## + nursery            1      6.86 4746.8 896.20
## + Walc               1      6.61 4747.1 896.22
## + activities         1      6.32 4747.4 896.24
## - age                1     55.75 4809.5 896.34
## + Medu               1      4.03 4749.7 896.39
## + high_freq_absent   1      2.94 4750.8 896.46
## + higher             1      1.39 4752.3 896.56
## + famrel             1      0.81 4752.9 896.60
## + Dalc               1      0.15 4753.6 896.65
## + Fedu               1      0.06 4753.6 896.65
## - schoolsup          1     63.93 4817.6 896.88
## - studytime          1     68.57 4822.3 897.18
## + reason             3     49.10 4704.6 897.38
## - famsize            1     73.95 4827.7 897.53
## - sex                1     74.40 4828.1 897.56
## - first_gen_college  1     86.27 4840.0 898.34
## + guardian           2      3.68 4750.0 898.41
## - Mjob               4    195.19 4948.9 899.37
## - romantic           1    103.42 4857.1 899.46
## - famsup             1    105.75 4859.5 899.61
## + Fjob               4     33.61 4720.1 900.41
## - absences           1    147.05 4900.8 902.28
```

```
## - freetime           1    160.34 4914.0 903.14
## - goout              1    219.35 4973.1 906.91
## - failed             1    497.54 5251.3 924.11
```

```
AIC(step.model_tr)
```

```
## [1] 1793.426
```

```
summary(step.model_tr)
```

```
##
## Call:
## lm(formula = G3 ~ sex + age + famsize + Mjob + studytime + schoolsup +
##     famsup + paid + romantic + freetime + goout + health + absences +
##     first_gen_college + failed, data = training)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11.5966  -1.9143   0.4216   2.6383  10.1119
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          15.61947    3.50460   4.457 1.18e-05 ***
## sexM                  1.09117    0.50610   2.156 0.031885 *
## age                  -0.37192    0.19928  -1.866 0.062990 .
## famsizeLE3            1.09276    0.50838   2.149 0.032403 *
## Mjobhealth            1.51975    1.04176   1.459 0.145669
## Mjobother             0.20870    0.69149   0.302 0.763006
## Mjobservices          1.41891    0.74064   1.916 0.056352 .
## Mjobteacher          -0.95496    0.99932  -0.956 0.340045
## studytime             0.60425    0.29194   2.070 0.039340 *
## schoolsupyes         -1.43855    0.71982  -1.998 0.046575 *
## famsupyes            -1.31666    0.51223  -2.570 0.010644 *
## paidyes               0.81591    0.49608   1.645 0.101084
## romanticyes          -1.27220    0.50050  -2.542 0.011534 *
## freetimelow          -1.56347    0.49398  -3.165 0.001712 **
## gooutlow              1.84589    0.49863   3.702 0.000255 ***
## healthlow             0.84074    0.46341   1.814 0.070648 .
## absences              0.08500    0.02804   3.031 0.002652 **
## first_gen_collegeyes -1.37377    0.59173  -2.322 0.020930 *
## failedyes            -3.43265    0.61568  -5.575 5.55e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.001 on 297 degrees of freedom
## Multiple R-squared:  0.3157, Adjusted R-squared:  0.2742
## F-statistic: 7.612 on 18 and 297 DF,  p-value: 2.832e-16
```

AIC of 1793.426 and adjusted R-squared of 0.2742.

Active variables: goout, absences, first_gen_college, failed, freetime, romantic, famsup, schoolsup, studytime, famsize, sex. Let's explore these with interaction terms.

```
activelm_tr <- lm(G3 ~ (sex + schoolsup + romantic + freetime + goout + absences + failed + studytime +
summary(activelm_tr)
```

```
##
```

```
## Call:
## lm(formula = G3 ~ (sex + schoolsup + romantic + freetime + goout +
##     absences + failed + studytime + first_gen_college + famsup +
##     famsize), data = training)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -12.5751  -2.1790   0.4765   2.7999  11.0657
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)          10.60588    0.99491  10.660  < 2e-16 ***
## sexM                  0.84292    0.50654   1.664 0.097129 .
## schoolsupyes         -0.92949    0.68924  -1.349 0.178478
## romanticyes          -1.35942    0.50766  -2.678 0.007813 **
## freetimelow          -1.42836    0.50007  -2.856 0.004581 **
## gooutlow              1.70615    0.50120   3.404 0.000753 ***
## absences              0.07599    0.02813   2.701 0.007297 **
## failedyes            -3.75325    0.59064  -6.355 7.63e-10 ***
## studytime             0.56316    0.29587   1.903 0.057930 .
## first_gen_collegeyes -1.34272    0.49968  -2.687 0.007603 **
## famsupyes            -0.87684    0.49917  -1.757 0.079996 .
## famsizeLE3            1.14706    0.51719   2.218 0.027304 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.097 on 304 degrees of freedom
## Multiple R-squared:  0.2655, Adjusted R-squared:  0.2389
## F-statistic: 9.987 on 11 and 304 DF,  p-value: 1.635e-15
```

```
AIC(activelm_tr)
```

```
## [1] 1801.82
```

AIC of 1801.82, Adjusted R-squared of 0.2389.

Adding all interaction terms:

```
interlm_tr <- lm(G3 ~ (sex + schoolsup + romantic + freetime + goout + absences + failed + studytime + f
summary(interlm_tr)
```

```
##
## Call:
## lm(formula = G3 ~ (sex + schoolsup + romantic + freetime + goout +
##     absences + failed + studytime + first_gen_college + famsup +
##     famsize)^2, data = training)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11.1133  -1.9546   0.3402   2.2558   8.0897
##
## Coefficients:
##                                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)                       17.828089   2.724408   6.544 3.39e-10 ***
## sexM                              -2.236645   1.989617  -1.124 0.262028
## schoolsupyes                       2.491733   2.900969   0.859 0.391205
```

```
## romanticyes                        -2.924267   2.589279  -1.129 0.259826
## freetimelow                        -2.019097   2.075748  -0.973 0.331642
## gooutlow                            1.696368   2.184918   0.776 0.438251
## absences                           -0.123817   0.172425  -0.718 0.473376
## failedyes                          -5.471058   2.886823  -1.895 0.059226 .
## studytime                          -2.406763   1.037396  -2.320 0.021150 *
## first_gen_collegeyes               -7.000153   1.957673  -3.576 0.000419 ***
## famsupyes                          -3.708275   1.989413  -1.864 0.063498 .
## famsizeLE3                          1.443291   2.318042   0.623 0.534095
## sexM:schoolsupyes                  -2.993395   1.677001  -1.785 0.075483 .
## sexM:romanticyes                    1.287244   1.071327   1.202 0.230682
## sexM:freetimelow                    1.086732   1.060899   1.024 0.306664
## sexM:gooutlow                      -0.667762   1.122071  -0.595 0.552307
## sexM:absences                      -0.009894   0.099224  -0.100 0.920654
## sexM:failedyes                     -3.771541   1.544833  -2.441 0.015328 *
## sexM:studytime                      0.167683   0.614759   0.273 0.785263
## sexM:first_gen_collegeyes           4.029339   1.103393   3.652 0.000317 ***
## sexM:famsupyes                      1.168833   1.082460   1.080 0.281279
## sexM:famsizeLE3                    -0.415000   1.199880  -0.346 0.729734
## schoolsupyes:romanticyes            2.301138   1.966379   1.170 0.243023
## schoolsupyes:freetimelow            0.798298   1.701002   0.469 0.639258
## schoolsupyes:gooutlow               0.312639   1.893847   0.165 0.869014
## schoolsupyes:absences              -0.244795   0.104775  -2.336 0.020265 *
## schoolsupyes:failedyes              2.951505   1.786648   1.652 0.099799 .
## schoolsupyes:studytime             -2.227824   0.914124  -2.437 0.015506 *
## schoolsupyes:first_gen_collegeyes   3.809002   1.644812   2.316 0.021384 *
## schoolsupyes:famsupyes             -0.150740   1.589188  -0.095 0.924508
## schoolsupyes:famsizeLE3            -3.380800   1.893210  -1.786 0.075357 .
## romanticyes:freetimelow            -1.775277   1.097661  -1.617 0.107074
## romanticyes:gooutlow               -0.260153   1.149870  -0.226 0.821196
## romanticyes:absences               -0.018206   0.079839  -0.228 0.819808
## romanticyes:failedyes              -0.209183   1.298112  -0.161 0.872111
## romanticyes:studytime               1.104782   0.738687   1.496 0.136023
## romanticyes:first_gen_collegeyes    0.487793   1.144907   0.426 0.670436
## romanticyes:famsupyes              -0.478762   1.171035  -0.409 0.683011
## romanticyes:famsizeLE3              0.419434   1.265768   0.331 0.740646
## freetimelow:gooutlow               -1.544626   0.993952  -1.554 0.121449
## freetimelow:absences                0.133237   0.079625   1.673 0.095522 .
## freetimelow:failedyes              -2.576119   1.337191  -1.927 0.055178 .
## freetimelow:studytime               0.592657   0.655277   0.904 0.366638
## freetimelow:first_gen_collegeyes    0.974338   1.060793   0.918 0.359246
## freetimelow:famsupyes              -0.383726   1.107122  -0.347 0.729187
## freetimelow:famsizeLE3             -0.642029   1.131025  -0.568 0.570783
## gooutlow:absences                  -0.067710   0.086300  -0.785 0.433442
## gooutlow:failedyes                  0.526401   1.319646   0.399 0.690312
## gooutlow:studytime                  1.208907   0.697376   1.734 0.084243 .
## gooutlow:first_gen_collegeyes       0.114464   1.128380   0.101 0.919282
## gooutlow:famsupyes                 -0.982709   1.089033  -0.902 0.367733
## gooutlow:famsizeLE3                -0.573774   1.175861  -0.488 0.626007
## absences:failedyes                  0.215436   0.070183   3.070 0.002381 **
## absences:studytime                 -0.006741   0.056951  -0.118 0.905869
## absences:first_gen_collegeyes       0.116287   0.081528   1.426 0.155018
## absences:famsupyes                  0.171607   0.072160   2.378 0.018156 *
## absences:famsizeLE3                -0.152720   0.081077  -1.884 0.060779 .
```

```
## failedyes:studytime               -0.340481   0.950143  -0.358 0.720387
## failedyes:first_gen_collegeyes     2.933576   1.635308   1.794 0.074043 .
## failedyes:famsupyes                0.694334   1.308619   0.531 0.596179
## failedyes:famsizeLE3               1.667873   1.465060   1.138 0.256034
## studytime:first_gen_collegeyes     0.989623   0.642846   1.539 0.124967
## studytime:famsupyes                1.177579   0.656217   1.794 0.073947 .
## studytime:famsizeLE3               0.913739   0.752968   1.214 0.226083
## first_gen_collegeyes:famsupyes     0.202676   1.124631   0.180 0.857130
## first_gen_collegeyes:famsizeLE3   -0.920305   1.184496  -0.777 0.437920
## famsupyes:famsizeLE3               0.116438   1.163129   0.100 0.920339
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.79 on 249 degrees of freedom
## Multiple R-squared:  0.4852, Adjusted R-squared:  0.3488
## F-statistic: 3.556 on 66 and 249 DF,  p-value: 3.206e-13
```

```
AIC(interlm_tr)
```

```
## [1] 1799.471
```

Significant interactions: absences*famsup, absences*failed schoolsup*first_gen_college, schoolsup*absences, schoolsup*studytime, sex*failed, sex*first_gen_college

```
interlm_tr1 <- lm(G3 ~ (sex + schoolsup + romantic + freetime + goout + absences + failed + studytime +
summary(interlm_tr1)
```

```
##
## Call:
## lm(formula = G3 ~ (sex + schoolsup + romantic + freetime + goout +
##     absences + failed + studytime + first_gen_college + famsup +
##     famsize + absences * famsup + absences * failed + schoolsup *
##     first_gen_college + schoolsup * absences + schoolsup * studytime +
##     sex * failed + sex * first_gen_college), data = training)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -12.4178  -2.2623   0.5875   2.6372   8.9101
##
## Coefficients:
##                                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)                       11.693293   1.020762  11.455  < 2e-16 ***
## sexM                              -0.887111   0.727008  -1.220 0.223349
## schoolsupyes                       0.352447   1.999087   0.176 0.860175
## romanticyes                       -1.643156   0.483126  -3.401 0.000763 ***
## freetimelow                       -1.265993   0.472756  -2.678 0.007821 **
## gooutlow                           1.556515   0.482777   3.224 0.001405 **
## absences                           0.006135   0.044127   0.139 0.889517
## failedyes                         -4.414005   0.906859  -4.867 1.84e-06 ***
## studytime                          0.805798   0.304397   2.647 0.008549 **
## first_gen_collegeyes              -3.405193   0.672109  -5.066 7.13e-07 ***
## famsupyes                         -1.267101   0.578374  -2.191 0.029243 *
## famsizeLE3                         1.136219   0.492371   2.308 0.021706 *
## absences:famsupyes                 0.066071   0.056944   1.160 0.246872
## absences:failedyes                 0.202897   0.061362   3.307 0.001061 **
## schoolsupyes:first_gen_collegeyes  4.459123   1.373647   3.246 0.001303 **
```

```
## schoolsupyes:absences             -0.099735   0.077493  -1.287 0.199090
## schoolsupyes:studytime            -1.634406   0.749457  -2.181 0.029984 *
## sexM:failedyes                    -2.147021   1.123717  -1.911 0.057013 .
## sexM:first_gen_collegeyes          3.729817   0.948321   3.933 0.000104 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.84 on 297 degrees of freedom
## Multiple R-squared:  0.3696, Adjusted R-squared:  0.3314
## F-statistic: 9.673 on 18 and 297 DF,  p-value: < 2.2e-16
```

```
AIC(interlm_tr1)
```

```
## [1] 1767.509
```

Schoolsup seems to have a high correlation with first_gen_college and studytime. Absences hasa high correlation with failed. Both of these make sense intuitively. Sex and first_Gen_college seems to have a high correlation, which does not make much sense intuitively and should be explored further.

Including only active variables and paring down the model:

```
interlm_tr2 <- lm(G3 ~ (romantic + freetime + goout + failed + studytime + first_gen_college + famsup +
summary(interlm_tr2)
```

```
##
## Call:
## lm(formula = G3 ~ (romantic + freetime + goout + failed + studytime +
##     first_gen_college + famsup + famsize + absences * failed +
##     schoolsup * first_gen_college + schoolsup * studytime + sex *
##     first_gen_college), data = training)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -12.1510  -2.1029   0.4616   2.4331   8.6819
##
## Coefficients:
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                      11.56650    1.00954  11.457  < 2e-16 ***
## romanticyes                      -1.57486    0.48280  -3.262 0.001234 **
## freetimelow                      -1.20937    0.47412  -2.551 0.011246 *
## gooutlow                          1.67484    0.47822   3.502 0.000532 ***
## failedyes                        -5.57431    0.70675  -7.887 5.80e-14 ***
## studytime                         0.82586    0.30416   2.715 0.007008 **
## first_gen_collegeyes             -3.32647    0.67292  -4.943 1.28e-06 ***
## famsupyes                        -0.96589    0.47204  -2.046 0.041608 *
## famsizeLE3                        1.19057    0.48812   2.439 0.015304 *
## absences                          0.02018    0.03122   0.646 0.518453
## schoolsupyes                      0.03990    1.96359   0.020 0.983804
## sexM                             -1.06718    0.72433  -1.473 0.141707
## failedyes:absences                0.23837    0.05954   4.004 7.87e-05 ***
## first_gen_collegeyes:schoolsupyes  4.18746    1.35602   3.088 0.002203 **
## studytime:schoolsupyes           -1.62659    0.75000  -2.169 0.030884 *
## first_gen_collegeyes:sexM         3.34855    0.92366   3.625 0.000339 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 3.857 on 300 degrees of freedom
## Multiple R-squared:  0.3576, Adjusted R-squared:  0.3255
## F-statistic: 11.14 on 15 and 300 DF,  p-value: < 2.2e-16
```

```
AIC(interlm_tr2)
```

```
## [1] 1767.442
```

AIC of 1767.442, Adjusted R-squared of 0.3255.

Using the model on the testing set:

```
pred.lm <- predict(interlm_tr2, testing)
pred.lm
```

```
##        11        17        18        21        31        32        34        43
## 12.717789 13.664748 10.446235 13.825867 12.859976 11.650605 13.829146 11.690972
##        46        58        59        60        72        76        78        80
##  9.281686 11.731340 13.877800 12.758157 14.268208 11.771707 10.434069 14.169365
##        89        94        95        97        98       115       116       119
## 11.376307 12.717789 12.961230  9.278423  6.181993 12.434563 11.225503  9.594648
##       120       130       133       149       150       152       155       160
## 13.121112 11.486639  7.957911  9.249891  6.963512  6.939987  8.730383  5.092277
##       174       175       178       180       187       194       196       200
##  1.533208 10.197155 11.044474 10.156482  9.312343 11.008302 13.299388 15.117727
##       224       226       227       229       231       235       239       240
## 11.672689  7.344933  8.884210 12.545147 13.581960 14.435933 10.397581  6.598803
##       243       244       250       254       260       264       269       273
## 12.515736 11.790639 11.812723 11.812723 12.834007 11.263805  9.812116 11.831628
##       279       281       282       283       284       288       292       300
##  5.768204 11.546389 11.876063 12.253786 10.946656 10.338282 13.543646 11.750747
##       304       315       322       328       329       336       340       341
## 11.043036  7.653679  8.058670 10.542833 13.219463 14.367006  9.472058  3.393286
##       347       358       369       378       385       386       389
## 12.049147 10.013290  6.990610 16.164352 11.045477 11.223437  8.907049
```

```
mse_test <- mean((pred.lm - testing$G3)^2)
testing$G3
```

```
##  [1]  9 14 10 15 12 17 12 18  6 15  9 16 10 10 11  5 10 10 14 15 10  9 16  8 13
## [26] 18 12  0 10 14 12 12  0  9  6 11 11 10 15 10 13  7 15  9 14  6 11  0  0 12
## [51] 15  8  0  9 10 11  8  8 10 12 10 12 15 16 18 13  9 10  9 15 10 11 16 11 10
## [76] 10  5 10  8
```

```
mse_test
```

```
## [1] 18.86165
```

## Regression random forest

```
library(randomForest)
```

```
## randomForest 4.6-14
```

```
## Type rfNews() to see new features/changes/bug fixes.
```

```
##
## Attaching package: 'randomForest'
```

```
## The following object is masked from 'package:dplyr':
##
##     combine
```

```
## The following object is masked from 'package:ggplot2':
##
##     margin
```

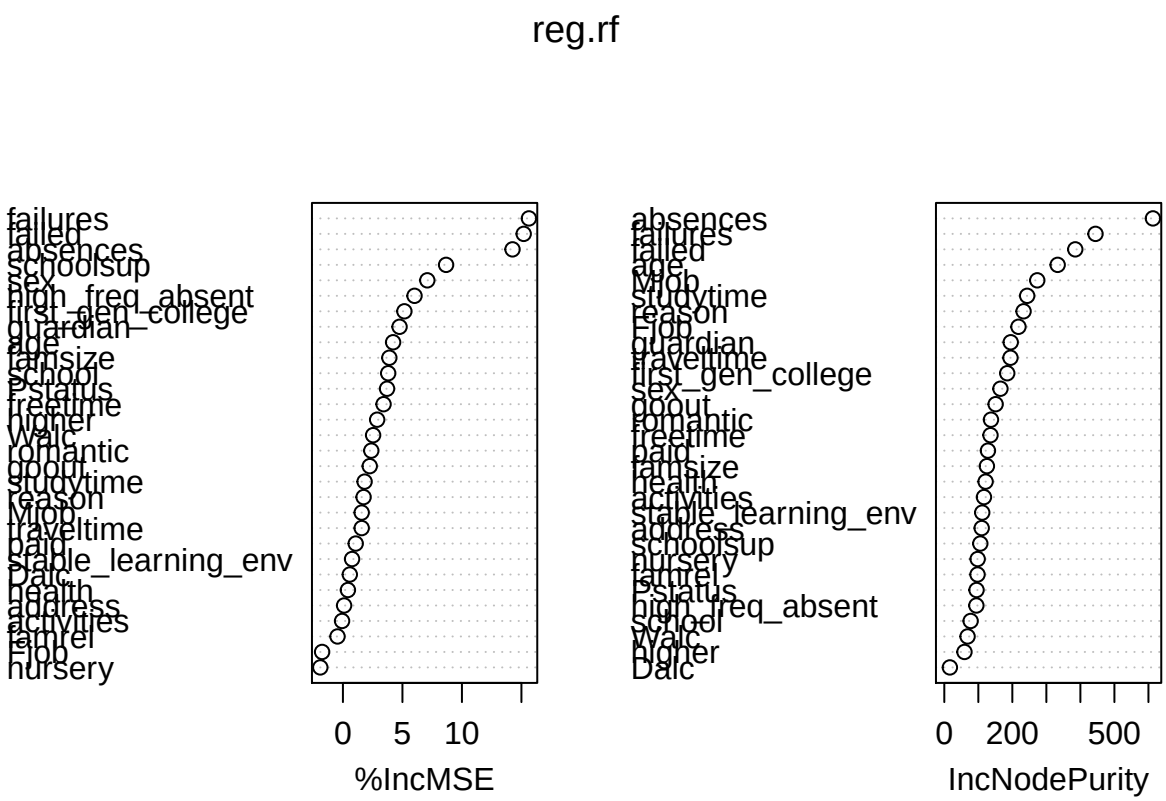
```
reg.rf <- randomForest(G3 ~ . -G1 -G2 -G3 -ord_g3 -famsup -internet -Medu -Fedu, data=training, mtry=3,
                       importance=TRUE, na.action=na.omit)
print(reg.rf)
```

```
##
## Call:
##  randomForest(formula = G3 ~ . - G1 - G2 - G3 - ord_g3 - famsup -      internet - Medu - Fedu, data =
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 3
##
##           Mean of squared residuals: 15.7478
##                     % Var explained: 28.37
```

```
importance(reg.rf)
```

```
##                        %IncMSE IncNodePurity
## school               3.80447280     77.42897
## sex                  7.09143437    165.01318
## age                  4.21634397    333.22110
## address              0.09820977    109.92863
## famsize              3.90060902    125.21849
## Pstatus              3.70861521     94.78058
## Mjob                 1.57725209    273.28599
## Fjob                -1.74817255    218.01969
## reason               1.73668264    232.99994
## guardian             4.75887862    195.24981
## traveltime           1.57696636    194.52003
## studytime            1.82188530    243.61645
## failures            15.63014737    444.44275
## schoolsup            8.66959339    105.82564
## paid                 1.07517244    128.26428
## activities          -0.07242459    116.55283
## nursery             -1.90198812     98.06232
## higher               2.87702720     59.29551
## romantic             2.38390323    137.22579
## famrel              -0.45664556     97.65292
## freetime             3.41409488    135.78663
## goout                2.25367103    150.92855
## Dalc                 0.57820540     16.43668
## Walc                 2.53614376     68.40345
## health               0.41808348    121.41972
## absences            14.25141252    613.20541
## first_gen_college    5.16458041    184.98607
## stable_learning_env  0.76697108    111.50717
## high_freq_absent     6.01629705     94.24896
## failed              15.19176562    384.93939
```

```
varImpPlot(reg.rf)
```




```
yhat_rf <- predict(reg.rf, newdata = testing)
mse_test.rf <- mean((yhat_rf - testing$G3)^2)

mse_test.rf
```

```
## [1] 14.21435
```

Improved test MSE compared to the linear model. test MSE = 14.085. 28.5% variation explained; mean of squared residuals is 15.7.

```
reg.rf1 <- randomForest(G3 ~ failed + absences + schoolsup + first_gen_college + age + studytime + famsi
                        importance=TRUE, na.action=na.omit)
print(reg.rf1)
```

```
##
## Call:
##  randomForest(formula = G3 ~ failed + absences + schoolsup + first_gen_college +      age + studytime
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 3
##
##           Mean of squared residuals: 14.89383
##                     % Var explained: 32.25
```

```
importance(reg.rf1)
```

```
##                     %IncMSE IncNodePurity
## failed            28.551062      775.6629
## absences          22.633636     1029.6972
```

```
## schoolsup         16.273472      208.8071
## first_gen_college 10.399713      282.9358
## age                5.966147      552.4141
## studytime          2.699172      395.4172
## famsize            6.705852      219.3213
## guardian           8.888185      300.7487
## freetime           3.046327      215.2759
## Mjob               4.311854      445.1541
## romantic           1.145756      195.0238
## traveltime         2.498400      338.0215
## sex                6.655714      231.6941
## goout              2.277766      222.8516
```

```
varImpPlot(reg.rf1)
```


```
yhat_rf1 <- predict(reg.rf1, newdata = testing)
mse_test.rf1 <- mean((yhat_rf1 - testing$G3)^2)

mse_test.rf1
```

```
## [1] 14.88391
```

Test MSE of 14.973; 32.4% of var explained by model; mean of squared residuals: 14.86

### Multicategory ordinal logit model

Due to the way grades are assigned as values between 0 and 20, we would like to consider G3 as an ordered categorical variable with 21 levels. This would allow us to fit a multicategory ordinal logistic model to the data.

We examine the EDA and active variables in the linear model to choose the predictors in our base model.

Fitting the base model:

```
require(foreign)
```

```
## Loading required package: foreign
```

```
require(nnet)
require(ggplot2)
require(reshape2)
```

```
## Loading required package: reshape2
```

```
##
## Attaching package: 'reshape2'
```

```
## The following object is masked from 'package:tidyr':
##
##     smiths
```

```
## The following object is masked from 'package:openintro':
##
##     tips
```

```
require(MASS)
require(Hmisc)
```

```
## Loading required package: Hmisc
```

```
## Loading required package: lattice
```

```
##
## Attaching package: 'lattice'
```

```
## The following objects are masked from 'package:openintro':
##
##     ethanol, lsegments
```

```
## Loading required package: survival
```

```
##
## Attaching package: 'survival'
```

```
## The following object is masked from 'package:openintro':
##
##     transplant
```

```
## Loading required package: Formula
```

```
##
## Attaching package: 'Hmisc'
```

```
## The following objects are masked from 'package:dplyr':
##
##     src, summarize
```

```
## The following object is masked from 'package:rvest':
##
##     html
```

```
## The following objects are masked from 'package:base':
##
##     format.pval, units
```

```r
mod <-polr(ord_g3 ~ . -G1 -G2 -G3, data = training)
summary(mod)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = ord_g3 ~ . - G1 - G2 - G3, data = training)
##
## Coefficients:
##                             Value Std. Error t value
## schoolMS                  0.32605    0.38236  0.8527
## sexM                      0.56589    0.24600  2.3004
## age                      -0.28037    0.10765 -2.6045
## addressU                  0.18757    0.28015  0.6695
## famsizeLE3                0.50097    0.23647  2.1185
## PstatusT                 -0.32472    0.34653 -0.9371
## Medu                      0.06932    0.18259  0.3796
## Fedu                     -0.08955    0.15325 -0.5844
## Mjobhealth                0.60023    0.54994  1.0915
## Mjobother                -0.05752    0.35774 -0.1608
## Mjobservices              0.54672    0.39896  1.3704
## Mjobteacher              -0.61096    0.52074 -1.1732
## Fjobhealth               -0.40733    0.69420 -0.5868
## Fjobother                -0.17855    0.48037 -0.3717
## Fjobservices             -0.05255    0.49757 -0.1056
## Fjobteacher               0.46618    0.66467  0.7014
## reasonhome                0.23177    0.26518  0.8740
## reasonother               0.25966    0.38080  0.6819
## reasonreputation          0.39833    0.28845  1.3809
## guardianmother            0.04580    0.26486  0.1729
## guardianother             0.46437    0.48249  0.9624
## traveltime               -0.14252    0.17642 -0.8079
## studytime                 0.37461    0.14709  2.5467
## failures                 -0.40709    0.28580 -1.4244
## schoolsupyes             -1.07299    0.33629 -3.1907
## famsupyes                -0.49298    0.54604 -0.9028
## paidyes                   0.20052    0.23526  0.8523
## activitiesyes            -0.11540    0.21736 -0.5309
## nurseryyes               -0.17096    0.26950 -0.6343
## higheryes                -0.15919    0.49945 -0.3187
## internetyes               0.39537    0.44970  0.8792
## romanticyes              -0.50355    0.23510 -2.1419
## famrellow                 0.05791    0.26647  0.2173
## freetimelow              -0.67456    0.23496 -2.8709
## gooutlow                  0.77564    0.24852  3.1210
## Dalclow                   0.07991    0.59539  0.1342
## Walclow                   0.25638    0.32121  0.7982
## healthlow                 0.29549    0.21720  1.3604
## absences                  0.02002    0.02009  0.9966
## first_gen_collegeyes     -0.70199    0.38869 -1.8060
## stable_learning_envyes   -0.16982    0.59977 -0.2831
## high_freq_absentyes      -0.16074    0.38422 -0.4184
## failedyes                -0.91443    0.54086 -1.6907
```

```
##
## Intercepts:
##       Value   Std. Error t value
## 0|4   -7.1685  2.3463    -3.0552
## 4|5   -7.1297  2.3461    -3.0390
## 5|6   -6.9426  2.3448    -2.9609
## 6|7   -6.5614  2.3424    -2.8012
## 7|8   -6.3439  2.3413    -2.7096
## 8|9   -5.7195  2.3376    -2.4467
## 9|10  -5.3221  2.3345    -2.2798
## 10|11 -4.6194  2.3278    -1.9844
## 11|12 -3.9471  2.3222    -1.6997
## 12|13 -3.5499  2.3203    -1.5299
## 13|14 -3.0007  2.3201    -1.2933
## 14|15 -2.4425  2.3202    -1.0527
## 15|16 -1.6383  2.3195    -0.7063
## 16|17 -1.0749  2.3222    -0.4629
## 17|18 -0.7489  2.3251    -0.3221
## 18|19  0.2523  2.3411     0.1078
## 19|20  2.1350  2.5097     0.8507
##
## Residual Deviance: 1513.116
## AIC: 1633.116
```

```
acc.ord <- predict(mod, training)
ctable <- table(training$G3, acc.ord)
round((sum(diag(ctable))/sum(ctable))*100,2)
```

```
## [1] 20.89
```

```
ctable
```

```
##     acc.ord
##       0  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
##   0  18  0  0  0  0  0  0 10  5  0  0  0  0  0  0  0  0  0
##   4   0  0  0  0  0  0  0  1  0  0  0  0  0  0  0  0  0  0
##   5   3  0  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0
##   6   1  0  0  0  0  0  0  9  1  0  0  0  1  0  0  0  0  0
##   7   4  0  0  0  0  0  0  1  3  0  0  0  0  0  0  0  0  0
##   8  11  0  0  0  0  0  0  8  7  0  0  0  1  0  0  0  0  0
##   9   6  0  0  0  0  0  0  8  6  0  0  0  0  0  0  0  0  0
##   10  8  0  0  0  0  0  0 14 12  0  0  0  5  0  0  0  0  0
##   11  2  0  0  0  0  0  0 12 20  0  1  0  5  0  0  0  0  0
##   12  3  0  0  0  0  0  0  3 12  0  0  0  5  0  0  0  0  0
##   13  5  0  0  0  0  0  0  2 17  0  0  0  4  0  0  0  0  0
##   14  1  0  0  0  0  0  0  2 12  0  0  0  8  0  0  0  0  0
##   15  0  0  0  0  0  0  0  3  7  0  1  0 14  0  0  0  0  0
##   16  0  0  0  0  0  0  0  1  4  0  0  0  7  0  0  0  0  0
##   17  0  0  0  0  0  0  0  0  3  0  0  0  2  0  0  0  0  0
##   18  0  0  0  0  0  0  0  1  4  0  0  0  4  0  0  0  0  0
##   19  0  0  0  0  0  0  0  0  1  0  0  0  4  0  0  0  0  0
##   20  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0
```

```
mod1 <- polr(ord_g3 ~ failed + high_freq_absent + romantic + internet + goout + first_gen_college + Wal
summary(mod1)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = ord_g3 ~ failed + high_freq_absent + romantic +
##     internet + goout + first_gen_college + Walc + sex + schoolsup +
##     famsup + absences + studytime + higher, data = training)
##
## Coefficients:
##                          Value Std. Error t value
## failedyes             -1.34171    0.27018 -4.9659
## high_freq_absentyes    0.03565    0.34970  0.1019
## romanticyes           -0.45766    0.22322 -2.0502
## internetyes            0.36012    0.27651  1.3024
## gooutlow               0.58461    0.22879  2.5552
## first_gen_collegeyes -0.66042    0.22335 -2.9568
## Walclow                0.33622    0.27525  1.2215
## sexM                   0.55216    0.22206  2.4865
## schoolsupyes          -0.69882    0.28905 -2.4177
## famsupyes             -0.48594    0.21594 -2.2503
## absences               0.01048    0.01726  0.6071
## studytime              0.25616    0.13427  1.9078
## higheryes              0.37412    0.45201  0.8277
##
## Intercepts:
##       Value   Std. Error t value
## 0|4   -1.6658  0.6572    -2.5347
## 4|5   -1.6293  0.6566    -2.4816
## 5|6   -1.4556  0.6534    -2.2276
## 6|7   -1.1027  0.6485    -1.7004
## 7|8   -0.9014  0.6467    -1.3939
## 8|9   -0.3219  0.6437    -0.5000
## 9|10   0.0449  0.6427     0.0698
## 10|11  0.6847  0.6438     1.0635
## 11|12  1.2954  0.6464     2.0040
## 12|13  1.6591  0.6479     2.5610
## 13|14  2.1640  0.6516     3.3212
## 14|15  2.6641  0.6579     4.0496
## 15|16  3.3940  0.6711     5.0577
## 16|17  3.9280  0.6858     5.7276
## 17|18  4.2419  0.6982     6.0754
## 18|19  5.2132  0.7670     6.7971
## 19|20  7.0544  1.1934     5.9112
##
## Residual Deviance: 1562.392
## AIC: 1622.392
```

```
(ctable <- coef(summary(mod1)))
```

```
##
## Re-fitting to get Hessian
```

```
##                            Value Std. Error     t value
## failedyes             -1.34171397 0.27018479 -4.96591237
## high_freq_absentyes    0.03565031 0.34969709  0.10194625
## romanticyes           -0.45766071 0.22322374 -2.05023314
```

```
## internetyes           0.36011512 0.27651008  1.30235803
## gooutlow              0.58461188 0.22879147  2.55521711
## first_gen_collegeyes -0.66042320 0.22335452 -2.95683831
## Walclow               0.33622440 0.27525303  1.22151026
## sexM                  0.55215988 0.22206496  2.48647905
## schoolsupyes         -0.69881781 0.28904608 -2.41766920
## famsupyes            -0.48593653 0.21594151 -2.25031553
## absences              0.01047719 0.01725748  0.60710999
## studytime             0.25615867 0.13426713  1.90782854
## higheryes             0.37411910 0.45201352  0.82767238
## 0|4                  -1.66581605 0.65721302 -2.53466683
## 4|5                  -1.62930927 0.65655494 -2.48160386
## 5|6                  -1.45558081 0.65342826 -2.22760613
## 6|7                  -1.10268571 0.64846971 -1.70044290
## 7|8                  -0.90144383 0.64670148 -1.39391027
## 8|9                  -0.32186448 0.64369588 -0.50002569
## 9|10                  0.04485165 0.64272846  0.06978319
## 10|11                 0.68472806 0.64384467  1.06349884
## 11|12                 1.29538659 0.64638677  2.00404255
## 12|13                 1.65914607 0.64785012  2.56100295
## 13|14                 2.16402771 0.65158608  3.32116935
## 14|15                 2.66414639 0.65787988  4.04959395
## 15|16                 3.39401724 0.67106437  5.05766269
## 16|17                 3.92801161 0.68580175  5.72761970
## 17|18                 4.24194365 0.69821069  6.07544927
## 18|19                 5.21317802 0.76696900  6.79711702
## 19|20                 7.05442354 1.19339185  5.91123825
```

Calculate and store p-values:

```
p1 <- pnorm(abs(ctable[, "t value"]), lower.tail = FALSE) * 2
(ctable <- cbind(ctable, "p value" = p1))
```

```
##                            Value Std. Error     t value      p value
## failedyes            -1.34171397 0.27018479 -4.96591237 6.837883e-07
## high_freq_absentyes   0.03565031 0.34969709  0.10194625 9.187993e-01
## romanticyes          -0.45766071 0.22322374 -2.05023314 4.034169e-02
## internetyes           0.36011512 0.27651008  1.30235803 1.927940e-01
## gooutlow              0.58461188 0.22879147  2.55521711 1.061216e-02
## first_gen_collegeyes -0.66042320 0.22335452 -2.95683831 3.108111e-03
## Walclow               0.33622440 0.27525303  1.22151026 2.218929e-01
## sexM                  0.55215988 0.22206496  2.48647905 1.290142e-02
## schoolsupyes         -0.69881781 0.28904608 -2.41766920 1.562027e-02
## famsupyes            -0.48593653 0.21594151 -2.25031553 2.442892e-02
## absences              0.01047719 0.01725748  0.60710999 5.437779e-01
## studytime             0.25615867 0.13426713  1.90782854 5.641338e-02
## higheryes             0.37411910 0.45201352  0.82767238 4.078561e-01
## 0|4                  -1.66581605 0.65721302 -2.53466683 1.125543e-02
## 4|5                  -1.62930927 0.65655494 -2.48160386 1.307926e-02
## 5|6                  -1.45558081 0.65342826 -2.22760613 2.590679e-02
## 6|7                  -1.10268571 0.64846971 -1.70044290 8.904765e-02
## 7|8                  -0.90144383 0.64670148 -1.39391027 1.633447e-01
## 8|9                  -0.32186448 0.64369588 -0.50002569 6.170570e-01
## 9|10                  0.04485165 0.64272846  0.06978319 9.443662e-01
## 10|11                 0.68472806 0.64384467  1.06349884 2.875558e-01
```

```
## 11|12                1.29538659 0.64638677  2.00404255 4.506550e-02
## 12|13                1.65914607 0.64785012  2.56100295 1.043705e-02
## 13|14                2.16402771 0.65158608  3.32116935 8.964113e-04
## 14|15                2.66414639 0.65787988  4.04959395 5.130658e-05
## 15|16                3.39401724 0.67106437  5.05766269 4.244263e-07
## 16|17                3.92801161 0.68580175  5.72761970 1.018496e-08
## 17|18                4.24194365 0.69821069  6.07544927 1.236411e-09
## 18|19                5.21317802 0.76696900  6.79711702 1.067334e-11
## 19|20                7.05442354 1.19339185  5.91123825 3.395455e-09
```

Confidence intervals for parameter estimates:

```
(ci1 <- confint(mod1))
```

```
## Waiting for profiling to be done...
```

```
##
## Re-fitting to get Hessian
```

```
##                              2.5 %      97.5 %
## failedyes            -1.876197497 -0.81556618
## high_freq_absentyes  -0.656411452  0.71764477
## romanticyes          -0.897663611 -0.02188466
## internetyes          -0.180649012  0.90497042
## gooutlow              0.137337761  1.03514595
## first_gen_collegeyes -1.100400976 -0.22416437
## Walclow              -0.203641426  0.87718770
## sexM                  0.118264255  0.98945878
## schoolsupyes         -1.268171885 -0.13267874
## famsupyes            -0.910849856 -0.06369438
## absences             -0.021851056  0.04656485
## studytime            -0.006577242  0.52033547
## higheryes            -0.505211121  1.27490555
```

Analyzing the p-values and confidence intervals allows us to determine whether the coefficient estimates are significant. Based on these, failed, romantic, goout, first_gen_college, sex, schoolsup, famsup, studytime seem to be active. (Studytime is dubious, but we will include it in the next model)

Refitting a model with these predictors:

```
mod2 <- polr(ord_g3 ~ failed + romantic + goout + first_gen_college + studytime + sex + schoolsup + fams
summary(mod2)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = ord_g3 ~ failed + romantic + goout + first_gen_college +
##     studytime + sex + schoolsup + famsup, data = training)
##
## Coefficients:
##                       Value Std. Error t value
## failedyes            -1.3882     0.2606  -5.327
## romanticyes          -0.4157     0.2160  -1.924
## gooutlow              0.6874     0.2119   3.245
## first_gen_collegeyes -0.6953     0.2189  -3.177
## studytime             0.2749     0.1333   2.062
## sexM                  0.4689     0.2127   2.205
```

```
## schoolsupyes         -0.6642     0.2881  -2.305
## famsupyes            -0.4203     0.2133  -1.970
##
## Intercepts:
##       Value   Std. Error t value
## 0|4   -2.5429  0.4453    -5.7101
## 4|5   -2.5068  0.4443    -5.6425
## 5|6   -2.3344  0.4396    -5.3103
## 6|7   -1.9834  0.4324    -4.5866
## 7|8   -1.7842  0.4294    -4.1546
## 8|9   -1.2081  0.4228    -2.8573
## 9|10  -0.8412  0.4200    -2.0027
## 10|11 -0.2072  0.4175    -0.4963
## 11|12  0.3981  0.4182     0.9519
## 12|13  0.7604  0.4192     1.8142
## 13|14  1.2610  0.4225     2.9847
## 14|15  1.7560  0.4295     4.0886
## 15|16  2.4801  0.4464     5.5558
## 16|17  3.0130  0.4678     6.4414
## 17|18  3.3261  0.4857     6.8484
## 18|19  4.2924  0.5793     7.4098
## 19|20  6.1276  1.0817     5.6650
##
## Residual Deviance: 1567.543
## AIC: 1617.543
```

```
(ctable <- coef(summary(mod2)))
```

```
##
## Re-fitting to get Hessian
```

```
##                           Value Std. Error    t value
## failedyes            -1.3881639  0.2605997 -5.3268047
## romanticyes          -0.4156752  0.2160358 -1.9241039
## gooutlow              0.6873737  0.2118547  3.2445526
## first_gen_collegeyes -0.6953188  0.2188570 -3.1770460
## studytime             0.2748992  0.1332997  2.0622646
## sexM                  0.4689357  0.2126871  2.2048153
## schoolsupyes         -0.6642084  0.2881418 -2.3051443
## famsupyes            -0.4203058  0.2133383 -1.9701374
## 0|4                  -2.5429074  0.4453387 -5.7100521
## 4|5                  -2.5067847  0.4442706 -5.6424726
## 5|6                  -2.3344286  0.4396061 -5.3102731
## 6|7                  -1.9834475  0.4324423 -4.5866175
## 7|8                  -1.7841536  0.4294407 -4.1545983
## 8|9                  -1.2081500  0.4228275 -2.8573116
## 9|10                 -0.8412191  0.4200487 -2.0026706
## 10|11                -0.2072168  0.4175067 -0.4963196
## 11|12                 0.3980517  0.4181620  0.9519078
## 12|13                 0.7604341  0.4191666  1.8141570
## 13|14                 1.2609616  0.4224815  2.9846550
## 14|15                 1.7559528  0.4294754  4.0885992
## 15|16                 2.4801341  0.4464006  5.5558481
## 16|17                 3.0129643  0.4677514  6.4413788
## 17|18                 3.3260960  0.4856779  6.8483581
```

```
## 18|19                 4.2923566  0.5792787  7.4098294
## 19|20                 6.1275584  1.0816527  5.6649962
```

```
p2 <- pnorm(abs(ctable[, "t value"]), lower.tail = FALSE) * 2
(ctable <- cbind(ctable, "p value" = p2))
```

```
##                           Value Std. Error    t value      p value
## failedyes            -1.3881639  0.2605997 -5.3268047 9.995554e-08
## romanticyes          -0.4156752  0.2160358 -1.9241039 5.434156e-02
## gooutlow              0.6873737  0.2118547  3.2445526 1.176353e-03
## first_gen_collegeyes -0.6953188  0.2188570 -3.1770460 1.487835e-03
## studytime             0.2748992  0.1332997  2.0622646 3.918255e-02
## sexM                  0.4689357  0.2126871  2.2048153 2.746706e-02
## schoolsupyes         -0.6642084  0.2881418 -2.3051443 2.115849e-02
## famsupyes            -0.4203058  0.2133383 -1.9701374 4.882263e-02
## 0|4                  -2.5429074  0.4453387 -5.7100521 1.129416e-08
## 4|5                  -2.5067847  0.4442706 -5.6424726 1.676252e-08
## 5|6                  -2.3344286  0.4396061 -5.3102731 1.094611e-07
## 6|7                  -1.9834475  0.4324423 -4.5866175 4.504849e-06
## 7|8                  -1.7841536  0.4294407 -4.1545983 3.258595e-05
## 8|9                  -1.2081500  0.4228275 -2.8573116 4.272462e-03
## 9|10                 -0.8412191  0.4200487 -2.0026706 4.521266e-02
## 10|11                -0.2072168  0.4175067 -0.4963196 6.196689e-01
## 11|12                 0.3980517  0.4181620  0.9519078 3.411438e-01
## 12|13                 0.7604341  0.4191666  1.8141570 6.965355e-02
## 13|14                 1.2609616  0.4224815  2.9846550 2.838983e-03
## 14|15                 1.7559528  0.4294754  4.0885992 4.339860e-05
## 15|16                 2.4801341  0.4464006  5.5558481 2.762670e-08
## 16|17                 3.0129643  0.4677514  6.4413788 1.183930e-10
## 17|18                 3.3260960  0.4856779  6.8483581 7.470236e-12
## 18|19                 4.2923566  0.5792787  7.4098294 1.264620e-13
## 19|20                 6.1275584  1.0816527  5.6649962 1.470278e-08
```

```
(ci2 <- confint(mod2))
```

```
## Waiting for profiling to be done...
##
## Re-fitting to get Hessian
```

```
##                             2.5 %       97.5 %
## failedyes            -1.90462685 -0.881708189
## romanticyes          -0.84097272  0.006566793
## gooutlow              0.27365841  1.104747592
## first_gen_collegeyes -1.12660028 -0.268012697
## studytime             0.01411035  0.537164395
## sexM                  0.05297154  0.887306542
## schoolsupyes         -1.23199282 -0.100060789
## famsupyes            -0.83978194 -0.002875816
```

AIC has decreased.

Based on the p-values and confidence intervals, romantic does not seem to be significant. Let's try excluding it.

Pared-down model again:

```
mod3 <- polr(ord_g3 ~ failed + goout + first_gen_college + sex + schoolsup + studytime, data = training
summary(mod3)
```

```
## Call:
## polr(formula = ord_g3 ~ failed + goout + first_gen_college +
##     sex + schoolsup + studytime, data = training, Hess = TRUE)
##
## Coefficients:
##                         Value Std. Error t value
## failedyes             -1.4470     0.2594  -5.577
## gooutlow               0.6862     0.2115   3.244
## first_gen_collegeyes -0.5623     0.2119  -2.654
## sexM                   0.5365     0.2106   2.547
## schoolsupyes          -0.6138     0.2822  -2.175
## studytime              0.2189     0.1311   1.670
##
## Intercepts:
##       Value   Std. Error t value
## 0|4   -2.1140  0.4116    -5.1354
## 4|5   -2.0782  0.4106    -5.0620
## 5|6   -1.9083  0.4060    -4.7005
## 6|7   -1.5631  0.3995    -3.9125
## 7|8   -1.3668  0.3969    -3.4435
## 8|9   -0.7982  0.3913    -2.0401
## 9|10  -0.4358  0.3892    -1.1199
## 10|11  0.1921  0.3879     0.4952
## 11|12  0.7943  0.3898     2.0379
## 12|13  1.1538  0.3918     2.9448
## 13|14  1.6485  0.3967     4.1551
## 14|15  2.1387  0.4054     5.2759
## 15|16  2.8588  0.4247     6.7305
## 16|17  3.3897  0.4478     7.5696
## 17|18  3.7015  0.4667     7.9310
## 18|19  4.6606  0.5642     8.2598
## 19|20  6.4828  1.0738     6.0371
##
## Residual Deviance: 1574.549
## AIC: 1620.549
```

```
(ctable <- coef(summary(mod3)))
```

```
##                           Value Std. Error    t value
## failedyes             -1.4470044  0.2594410 -5.5773921
## gooutlow               0.6862095  0.2115274  3.2440692
## first_gen_collegeyes -0.5623425  0.2119141 -2.6536341
## sexM                   0.5364682  0.2106266  2.5470106
## schoolsupyes          -0.6138372  0.2821635 -2.1754659
## studytime              0.2188984  0.1310851  1.6698957
## 0|4                   -2.1139669  0.4116495 -5.1353568
## 4|5                   -2.0782289  0.4105540 -5.0620109
## 5|6                   -1.9083008  0.4059759 -4.7005269
## 6|7                   -1.5630672  0.3995011 -3.9125480
## 7|8                   -1.3667896  0.3969204 -3.4434854
## 8|9                   -0.7982483  0.3912773 -2.0401089
## 9|10                  -0.4358495  0.3891718 -1.1199410
## 10|11                  0.1920664  0.3878675  0.4951856
## 11|12                  0.7942916  0.3897682  2.0378563
## 12|13                  1.1537589  0.3917941  2.9448095
```

```
## 13|14                 1.6485090  0.3967448  4.1550867
## 14|15                 2.1387107  0.4053722  5.2759186
## 15|16                 2.8587993  0.4247500  6.7305461
## 16|17                 3.3897018  0.4478022  7.5696401
## 17|18                 3.7014831  0.4667133  7.9309568
## 18|19                 4.6605957  0.5642498  8.2598092
## 19|20                 6.4827907  1.0738176  6.0371431
```

```
p3 <- pnorm(abs(ctable[, "t value"]), lower.tail = FALSE) * 2
(ctable <- cbind(ctable, "p value" = p3))
```

```
##                            Value Std. Error    t value      p value
## failedyes             -1.4470044  0.2594410 -5.5773921 2.441512e-08
## gooutlow               0.6862095  0.2115274  3.2440692 1.178351e-03
## first_gen_collegeyes -0.5623425  0.2119141 -2.6536341 7.963013e-03
## sexM                   0.5364682  0.2106266  2.5470106 1.086501e-02
## schoolsupyes          -0.6138372  0.2821635 -2.1754659 2.959522e-02
## studytime              0.2188984  0.1310851  1.6698957 9.494000e-02
## 0|4                   -2.1139669  0.4116495 -5.1353568 2.816093e-07
## 4|5                   -2.0782289  0.4105540 -5.0620109 4.148574e-07
## 5|6                   -1.9083008  0.4059759 -4.7005269 2.594911e-06
## 6|7                   -1.5630672  0.3995011 -3.9125480 9.132736e-05
## 7|8                   -1.3667896  0.3969204 -3.4434854 5.742675e-04
## 8|9                   -0.7982483  0.3912773 -2.0401089 4.133948e-02
## 9|10                  -0.4358495  0.3891718 -1.1199410 2.627389e-01
## 10|11                  0.1920664  0.3878675  0.4951856 6.204691e-01
## 11|12                  0.7942916  0.3897682  2.0378563 4.156431e-02
## 12|13                  1.1537589  0.3917941  2.9448095 3.231536e-03
## 13|14                  1.6485090  0.3967448  4.1550867 3.251642e-05
## 14|15                  2.1387107  0.4053722  5.2759186 1.320927e-07
## 15|16                  2.8587993  0.4247500  6.7305461 1.690275e-11
## 16|17                  3.3897018  0.4478022  7.5696401 3.742596e-14
## 17|18                  3.7014831  0.4667133  7.9309568 2.174638e-15
## 18|19                  4.6605957  0.5642498  8.2598092 1.459055e-16
## 19|20                  6.4827907  1.0738176  6.0371431 1.568666e-09
```

```
(ci3 <- confint(mod3))
```

```
## Waiting for profiling to be done...
```

```
##                              2.5 %      97.5 %
## failedyes             -1.96148845 -0.94318819
## gooutlow               0.27307924  1.10288470
## first_gen_collegeyes -0.97950820 -0.14817187
## sexM                   0.12485281  0.95095558
## schoolsupyes          -1.16913473 -0.06070744
## studytime             -0.03766773  0.47670960
```

All predictors are significant, but AIC has increased compared to mod2.

Evaluating accuracy of the model for the training set:

```
acc.ord3 <- predict(mod3, training)
ctable <- table(training$G3, acc.ord3)
round((sum(diag(ctable))/sum(ctable))*100,2)
```

```
## [1] 17.09
```

```
ctable
```

```
##     acc.ord3
##       0  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
##   0  16  0  0  0  0  0  0  7  7  0  0  0  3  0  0  0  0  0
##   4   1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
##   5   2  0  0  0  0  0  0  3  0  0  0  0  0  0  0  0  0  0
##   6   1  0  0  0  0  0  0  6  5  0  0  0  0  0  0  0  0  0
##   7   5  0  0  0  0  0  0  0  1  0  0  0  2  0  0  0  0  0
##   8  12  0  0  0  0  0  0  4  9  0  0  0  2  0  0  0  0  0
##   9   6  0  0  0  0  0  0  4  9  0  0  0  1  0  0  0  0  0
##   10  8  0  0  0  0  0  0  6 20  0  0  0  5  0  0  0  0  0
##   11  4  0  0  0  0  0  0  8 23  0  0  0  5  0  0  0  0  0
##   12  3  0  0  0  0  0  0  5 11  0  0  0  4  0  0  0  0  0
##   13  5  0  0  0  0  0  0  3 17  0  0  0  3  0  0  0  0  0
##   14  1  0  0  0  0  0  0  3  8  0  0  0 11  0  0  0  0  0
##   15  0  0  0  0  0  0  0  2 14  0  0  0  9  0  0  0  0  0
##   16  0  0  0  0  0  0  0  2  6  0  0  0  4  0  0  0  0  0
##   17  0  0  0  0  0  0  0  1  3  0  0  0  1  0  0  0  0  0
##   18  1  0  0  0  0  0  0  1  5  0  0  0  2  0  0  0  0  0
##   19  0  0  0  0  0  0  0  0  3  0  0  0  2  0  0  0  0  0
##   20  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0
```

Very terrible accuracy even for the training set.

What if we add interaction terms?

Let's base our interaction terms on the discussion for the linear model.

```
mod4 <- polr(ord_g3 ~ failed + goout + romantic +  first_gen_college + sex + schoolsup + sex*schoolsup +
summary(mod4)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = ord_g3 ~ failed + goout + romantic + first_gen_college +
##     sex + schoolsup + sex * schoolsup + sex * first_gen_college +
##     schoolsup * failed + schoolsup * studytime + schoolsup *
##     first_gen_college + studytime * famsup, data = training)
##
## Coefficients:
##                                      Value Std. Error  t value
## failedyes                          -1.72945     0.2981 -5.80124
## gooutlow                            0.67401     0.2169  3.10806
## romanticyes                        -0.48910     0.2204 -2.21930
## first_gen_collegeyes               -1.43664     0.3180 -4.51738
## sexM                               -0.01446     0.3391 -0.04265
## schoolsupyes                        0.73242     0.9305  0.78712
## studytime                           0.36175     0.2487  1.45475
## famsupyes                          -0.76421     0.5894 -1.29664
## sexM:schoolsupyes                  -1.06747     0.6217 -1.71701
## first_gen_collegeyes:sexM           1.06194     0.4232  2.50904
## failedyes:schoolsupyes              1.15774     0.6593  1.75607
## schoolsupyes:studytime             -1.11414     0.3374 -3.30178
## first_gen_collegeyes:schoolsupyes   1.59232     0.6093  2.61341
## studytime:famsupyes                 0.14783     0.2850  0.51876
```

```
##
## Intercepts:
##       Value   Std. Error t value
## 0|4   -3.0101  0.5949    -5.0599
## 4|5   -2.9717  0.5939    -5.0034
## 5|6   -2.7903  0.5898    -4.7309
## 6|7   -2.4230  0.5833    -4.1537
## 7|8   -2.2159  0.5806    -3.8163
## 8|9   -1.6123  0.5757    -2.8006
## 9|10  -1.2173  0.5741    -2.1202
## 10|11 -0.5423  0.5738    -0.9451
## 11|12  0.0965  0.5744     0.1680
## 12|13  0.4842  0.5739     0.8438
## 13|14  1.0192  0.5741     1.7752
## 14|15  1.5345  0.5779     2.6551
## 15|16  2.2702  0.5892     3.8531
## 16|17  2.8082  0.6045     4.6455
## 17|18  3.1241  0.6180     5.0554
## 18|19  4.0937  0.6937     5.9014
## 19|20  5.9292  1.1498     5.1569
##
## Residual Deviance: 1537.762
## AIC: 1599.762
```

```
(ctable <- coef(summary(mod4)))
```

```
##
## Re-fitting to get Hessian
```

```
##                                       Value Std. Error     t value
## failedyes                        -1.72945368  0.2981178 -5.80124295
## gooutlow                          0.67400726  0.2168580  3.10805786
## romanticyes                      -0.48909643  0.2203829 -2.21930313
## first_gen_collegeyes             -1.43663982  0.3180252 -4.51737778
## sexM                             -0.01446239  0.3390652 -0.04265371
## schoolsupyes                      0.73241720  0.9305008  0.78712151
## studytime                         0.36174519  0.2486653  1.45474731
## famsupyes                        -0.76421191  0.5893770 -1.29664348
## sexM:schoolsupyes                -1.06746616  0.6217004 -1.71701055
## first_gen_collegeyes:sexM         1.06194139  0.4232461  2.50904014
## failedyes:schoolsupyes            1.15773926  0.6592797  1.75606684
## schoolsupyes:studytime           -1.11413949  0.3374358 -3.30178248
## first_gen_collegeyes:schoolsupyes 1.59232262  0.6092889  2.61341153
## studytime:famsupyes               0.14782789  0.2849627  0.51876227
## 0|4                              -3.01008158  0.5948850 -5.05993887
## 4|5                              -2.97166463  0.5939322 -5.00337322
## 5|6                              -2.79029263  0.5898075 -4.73085276
## 6|7                              -2.42295680  0.5833207 -4.15373034
## 7|8                              -2.21585268  0.5806252 -3.81632165
## 8|9                              -1.61234628  0.5757246 -2.80055115
## 9|10                             -1.21732081  0.5741468 -2.12022571
## 10|11                            -0.54231022  0.5738069 -0.94510930
## 11|12                             0.09649365  0.5743725  0.16799839
## 12|13                             0.48423331  0.5738879  0.84377688
## 13|14                             1.01921806  0.5741418  1.77520259
```

```
## 14|15                                1.53449674  0.5779426  2.65510251
## 15|16                                2.27018077  0.5891862  3.85307839
## 16|17                                2.80819116  0.6045010  4.64546978
## 17|18                                3.12405658  0.6179583  5.05544881
## 18|19                                4.09365582  0.6936810  5.90135194
## 19|20                                5.92920227  1.1497705  5.15685736
```

```
p4 <- pnorm(abs(ctable[, "t value"]), lower.tail = FALSE) * 2
(ctable <- cbind(ctable, "p value" = p4))
```

```
##                                       Value Std. Error     t value
## failedyes                        -1.72945368  0.2981178 -5.80124295
## gooutlow                          0.67400726  0.2168580  3.10805786
## romanticyes                      -0.48909643  0.2203829 -2.21930313
## first_gen_collegeyes             -1.43663982  0.3180252 -4.51737778
## sexM                             -0.01446239  0.3390652 -0.04265371
## schoolsupyes                      0.73241720  0.9305008  0.78712151
## studytime                         0.36174519  0.2486653  1.45474731
## famsupyes                        -0.76421191  0.5893770 -1.29664348
## sexM:schoolsupyes                -1.06746616  0.6217004 -1.71701055
## first_gen_collegeyes:sexM         1.06194139  0.4232461  2.50904014
## failedyes:schoolsupyes            1.15773926  0.6592797  1.75606684
## schoolsupyes:studytime           -1.11413949  0.3374358 -3.30178248
## first_gen_collegeyes:schoolsupyes  1.59232262  0.6092889  2.61341153
## studytime:famsupyes               0.14782789  0.2849627  0.51876227
## 0|4                              -3.01008158  0.5948850 -5.05993887
## 4|5                              -2.97166463  0.5939322 -5.00337322
## 5|6                              -2.79029263  0.5898075 -4.73085276
## 6|7                              -2.42295680  0.5833207 -4.15373034
## 7|8                              -2.21585268  0.5806252 -3.81632165
## 8|9                              -1.61234628  0.5757246 -2.80055115
## 9|10                             -1.21732081  0.5741468 -2.12022571
## 10|11                            -0.54231022  0.5738069 -0.94510930
## 11|12                             0.09649365  0.5743725  0.16799839
## 12|13                             0.48423331  0.5738879  0.84377688
## 13|14                             1.01921806  0.5741418  1.77520259
## 14|15                             1.53449674  0.5779426  2.65510251
## 15|16                             2.27018077  0.5891862  3.85307839
## 16|17                             2.80819116  0.6045010  4.64546978
## 17|18                             3.12405658  0.6179583  5.05544881
## 18|19                             4.09365582  0.6936810  5.90135194
## 19|20                             5.92920227  1.1497705  5.15685736
##                                      p value
## failedyes                        6.582515e-09
## gooutlow                         1.883212e-03
## romanticyes                      2.646611e-02
## first_gen_collegeyes             6.261014e-06
## sexM                             9.659776e-01
## schoolsupyes                     4.312107e-01
## studytime                        1.457392e-01
## famsupyes                        1.947539e-01
## sexM:schoolsupyes                8.597724e-02
## first_gen_collegeyes:sexM        1.210597e-02
## failedyes:schoolsupyes           7.907700e-02
## schoolsupyes:studytime           9.607254e-04
```

```
## first_gen_collegeyes:schoolsupyes 8.964329e-03
## studytime:famsupyes               6.039265e-01
## 0|4                               4.193909e-07
## 4|5                               5.633572e-07
## 5|6                               2.235787e-06
## 6|7                               3.270986e-05
## 7|8                               1.354559e-04
## 8|9                               5.101542e-03
## 9|10                              3.398702e-02
## 10|11                             3.446031e-01
## 11|12                             8.665845e-01
## 12|13                             3.987941e-01
## 13|14                             7.586444e-02
## 14|15                             7.928431e-03
## 15|16                             1.166420e-04
## 16|17                             3.393034e-06
## 17|18                             4.293798e-07
## 18|19                             3.605349e-09
## 19|20                             2.511290e-07
```

```
(ci4 <- confint(mod4))
```

```
## Waiting for profiling to be done...
##
## Re-fitting to get Hessian
```

```
##                                       2.5 %      97.5 %
## failedyes                        -2.3214364 -1.15123396
## gooutlow                          0.2503920  1.10114465
## romanticyes                      -0.9230151 -0.05837766
## first_gen_collegeyes             -2.0646870 -0.81670972
## sexM                             -0.6799620  0.65071516
## schoolsupyes                     -1.0998497  2.56413384
## studytime                        -0.1227550  0.85203523
## famsupyes                        -1.9233145  0.38932033
## sexM:schoolsupyes                -2.2962304  0.15377624
## first_gen_collegeyes:sexM         0.2363092  1.89633281
## failedyes:schoolsupyes           -0.1337302  2.46425196
## schoolsupyes:studytime           -1.7820611 -0.45214925
## first_gen_collegeyes:schoolsupyes  0.4009686  2.79629741
## studytime:famsupyes              -0.4093914  0.70866271
```

AIC has decreased significantly compared to the previous models without interaction terms, by nearly 20. However, in this model, sex, its interaction with schoolsup, and its interaction with first_gen_college all seem to be insignificant. The interaction between studytime and famsup and failed and schoolsup do not seem significant either, so let us remove it to pare down the model:

```
mod5 <- polr(ord_g3 ~ failed + goout + romantic + schoolsup + first_gen_college + schoolsup * studytime
summary(mod5)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = ord_g3 ~ failed + goout + romantic + schoolsup +
##     first_gen_college + schoolsup * studytime + schoolsup * first_gen_college,
##     data = training)
```

```
##
## Coefficients:
##                                    Value Std. Error  t value
## failedyes                        -1.39146     0.2622 -5.30667
## gooutlow                          0.59649     0.2134  2.79476
## romanticyes                      -0.50391     0.2163 -2.32943
## schoolsupyes                      0.03364     0.8300  0.04052
## first_gen_collegeyes             -0.85007     0.2317 -3.66947
## studytime                         0.29305     0.1393  2.10388
## schoolsupyes:studytime           -0.85318     0.3244 -2.62985
## schoolsupyes:first_gen_collegeyes  1.52426     0.5720  2.66499
##
## Intercepts:
##       Value   Std. Error t value
## 0|4   -2.6921  0.4042    -6.6607
## 4|5   -2.6558  0.4029    -6.5914
## 5|6   -2.4839  0.3975    -6.2485
## 6|7   -2.1376  0.3891    -5.4942
## 7|8   -1.9409  0.3852    -5.0386
## 8|9   -1.3590  0.3772    -3.6032
## 9|10  -0.9824  0.3739    -2.6277
## 10|11 -0.3366  0.3707    -0.9081
## 11|12  0.2744  0.3708     0.7400
## 12|13  0.6418  0.3719     1.7259
## 13|14  1.1514  0.3752     3.0688
## 14|15  1.6489  0.3824     4.3124
## 15|16  2.3707  0.4009     5.9140
## 16|17  2.9048  0.4245     6.8436
## 17|18  3.2188  0.4440     7.2496
## 18|19  4.1810  0.5450     7.6720
## 19|20  6.0069  1.0636     5.6479
##
## Residual Deviance: 1563.245
## AIC: 1613.245
```

```
(ctable <- coef(summary(mod5)))
```

```
##
## Re-fitting to get Hessian
##                                         Value Std. Error     t value
## failedyes                        -1.39146287  0.2622101 -5.30667226
## gooutlow                          0.59648735  0.2134306  2.79475999
## romanticyes                      -0.50390805  0.2163229 -2.32942552
## schoolsupyes                      0.03363511  0.8300358  0.04052249
## first_gen_collegeyes             -0.85006782  0.2316595 -3.66947101
## studytime                         0.29304592  0.1392885  2.10387705
## schoolsupyes:studytime           -0.85318089  0.3244225 -2.62984500
## schoolsupyes:first_gen_collegeyes  1.52425650  0.5719558  2.66498990
## 0|4                              -2.69208825  0.4041720 -6.66074948
## 4|5                              -2.65581637  0.4029201 -6.59142141
## 5|6                              -2.48392676  0.3975209 -6.24854363
## 6|7                              -2.13758424  0.3890606 -5.49421935
## 7|8                              -1.94093740  0.3852119 -5.03862266
## 8|9                              -1.35895482  0.3771508 -3.60321358
```

```
## 9|10                                -0.98243182  0.3738798 -2.62766733
## 10|11                               -0.33664864  0.3707238 -0.90808488
## 11|12                                0.27441039  0.3708471  0.73995555
## 12|13                                0.64181542  0.3718808  1.72586325
## 13|14                                1.15140976  0.3751961  3.06882090
## 14|15                                1.64894914  0.3823753  4.31238440
## 15|16                                2.37070007  0.4008641  5.91397458
## 16|17                                2.90477643  0.4244524  6.84358578
## 17|18                                3.21877485  0.4439939  7.24959282
## 18|19                                4.18096474  0.5449623  7.67202626
## 19|20                                6.00685744  1.0635640  5.64785684
```

```
p5 <- pnorm(abs(ctable[, "t value"]), lower.tail = FALSE) * 2
(ctable <- cbind(ctable, "p value" = p5))
```

```
##                                       Value Std. Error     t value
## failedyes                        -1.39146287  0.2622101 -5.30667226
## gooutlow                          0.59648735  0.2134306  2.79475999
## romanticyes                      -0.50390805  0.2163229 -2.32942552
## schoolsupyes                      0.03363511  0.8300358  0.04052249
## first_gen_collegeyes             -0.85006782  0.2316595 -3.66947101
## studytime                         0.29304592  0.1392885  2.10387705
## schoolsupyes:studytime           -0.85318089  0.3244225 -2.62984500
## schoolsupyes:first_gen_collegeyes  1.52425650  0.5719558  2.66498990
## 0|4                              -2.69208825  0.4041720 -6.66074948
## 4|5                              -2.65581637  0.4029201 -6.59142141
## 5|6                              -2.48392676  0.3975209 -6.24854363
## 6|7                              -2.13758424  0.3890606 -5.49421935
## 7|8                              -1.94093740  0.3852119 -5.03862266
## 8|9                              -1.35895482  0.3771508 -3.60321358
## 9|10                             -0.98243182  0.3738798 -2.62766733
## 10|11                            -0.33664864  0.3707238 -0.90808488
## 11|12                             0.27441039  0.3708471  0.73995555
## 12|13                             0.64181542  0.3718808  1.72586325
## 13|14                             1.15140976  0.3751961  3.06882090
## 14|15                             1.64894914  0.3823753  4.31238440
## 15|16                             2.37070007  0.4008641  5.91397458
## 16|17                             2.90477643  0.4244524  6.84358578
## 17|18                             3.21877485  0.4439939  7.24959282
## 18|19                             4.18096474  0.5449623  7.67202626
## 19|20                             6.00685744  1.0635640  5.64785684
##                                       p value
## failedyes                        1.116447e-07
## gooutlow                         5.193826e-03
## romanticyes                      1.983653e-02
## schoolsupyes                     9.676766e-01
## first_gen_collegeyes             2.430529e-04
## studytime                        3.538917e-02
## schoolsupyes:studytime           8.542381e-03
## schoolsupyes:first_gen_collegeyes 7.699064e-03
## 0|4                              2.724347e-11
## 4|5                              4.356354e-11
## 5|6                              4.142975e-10
## 6|7                              3.924425e-08
## 7|8                              4.688939e-07
```

```
## 8|9                                  3.143071e-04
## 9|10                                 8.597255e-03
## 10|11                                3.638334e-01
## 11|12                                4.593270e-01
## 12|13                                8.437202e-02
## 13|14                                2.149054e-03
## 14|15                                1.615033e-05
## 15|16                                3.339494e-09
## 16|17                                7.723504e-12
## 17|18                                4.180264e-13
## 18|19                                1.693003e-14
## 19|20                                1.624604e-08
```

```
(ci5 <- confint(mod5))
```

```
## Waiting for profiling to be done...
##
## Re-fitting to get Hessian
```

```
##                                           2.5 %      97.5 %
## failedyes                           -1.91099915 -0.88183866
## gooutlow                             0.17940546  1.01668340
## romanticyes                         -0.92995496 -0.08125812
## schoolsupyes                        -1.60642853  1.65956106
## first_gen_collegeyes                -1.30698473 -0.39813983
## studytime                            0.02039631  0.56697874
## schoolsupyes:studytime              -1.49158352 -0.21490640
## schoolsupyes:first_gen_collegeyes    0.40814640  2.65646321
```

This has resulted in an increase in the AIC, which is still lower than the first three models.

Let's check the accuracy of this model with interaction terms:

```
acc.ord4 <- predict(mod4, training)
ctable <- table(training$G3, acc.ord4)
round((sum(diag(ctable))/sum(ctable))*100,2)
```

```
## [1] 19.94
```

```
ctable
```

```
##     acc.ord4
##       0  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
##   0  18  0  0  0  0  0  0 10  3  0  1  0  1  0  0  0  0  0
##   4   1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
##   5   4  0  0  0  0  0  0  1  0  0  0  0  0  0  0  0  0  0
##   6   1  0  0  0  0  0  0 10  1  0  0  0  0  0  0  0  0  0
##   7   4  0  0  0  0  0  0  1  1  0  0  0  2  0  0  0  0  0
##   8  14  0  0  0  0  0  0  7  3  0  0  0  3  0  0  0  0  0
##   9   8  0  0  0  0  0  0  4  6  0  2  0  0  0  0  0  0  0
##   10  5  0  0  0  0  0  0 14 10  0  2  0  8  0  0  0  0  0
##   11  5  0  0  0  0  0  0 13 15  0  1  0  6  0  0  0  0  0
##   12  3  0  0  0  0  0  0  7  9  0  1  0  3  0  0  0  0  0
##   13  4  0  0  0  0  0  0  5 10  0  3  0  6  0  0  0  0  0
##   14  0  0  0  0  0  0  0  2  8  0  4  0  9  0  0  0  0  0
##   15  0  0  0  0  0  0  0  3  8  0  1  0 13  0  0  0  0  0
##   16  0  0  0  0  0  0  0  0  9  0  0  0  3  0  0  0  0  0
##   17  0  0  0  0  0  0  0  0  3  0  0  0  2  0  0  0  0  0
```

```
##   18  1  0  0  0  0  0  0  0  4  0  2  0  2  0  0  0  0  0
##   19  0  0  0  0  0  0  0  0  2  0  0  0  3  0  0  0  0  0
##   20  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0
```

The accuracy is even lower than mod3, at only 19.94% for the training set.

Checking on testing set:

```
pred.ord3 <- predict(mod3, testing)
ctable <- table(testing$G3, pred.ord3)
round((sum(diag(ctable))/sum(ctable))*100,2)
```

```
## [1] 8.86
```

```
pred.ord4 <- predict(mod4, testing)
ctable <- table(testing$G3, pred.ord4)
round((sum(diag(ctable))/sum(ctable))*100,2)
```

```
## [1] 11.39
```

```
pred.ord5 <- predict(mod5, testing)
ctable <- table(testing$G3, pred.ord5)
round((sum(diag(ctable))/sum(ctable))*100,2)
```

```
## [1] 10.13
```

Accuracy rates are even lower, at 8.86%, 11.39%, and 10.13%.

Highly inaccurate model, not a good fit for the data.

### Recoding g3 with larger categories

```
library(car)
```

```
## Loading required package: carData
```

```
##
## Attaching package: 'car'
```

```
## The following object is masked from 'package:dplyr':
##
##     recode
```

```
## The following object is masked from 'package:purrr':
##
##     some
```

```
## The following object is masked from 'package:openintro':
##
##     densityPlot
```

```
data <- data %>%
  mutate(cat_g3 = case_when(
    G3 == 0 ~ "Poor",
    G3 <= 9 ~ "Weak",
    G3 <= 13 ~ "Sufficient",
    G3 <= 15 ~ "Good",
    G3 <= 17 ~"Very Good",
    G3 <= 20 ~ "Excellent"
  ))
```

```
data <- data %>%
  mutate(cat_g3 = factor(cat_g3, levels=c("Poor", "Weak", "Sufficient", "Good", "Very Good", "Excellent

set.seed(3)
train_ind <- sample(x = nrow(data), size = 0.8 * nrow(data))
test_ind_neg <- -train_ind
ftrain <- data[train_ind, ]
ftest <- data[test_ind_neg, ]
```

Trying out a multicat ordinal logit on this:

```
mod6 <- polr(cat_g3 ~ failed + goout + romantic + schoolsup + first_gen_college + schoolsup * studytime
summary(mod6)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = cat_g3 ~ failed + goout + romantic + schoolsup +
##     first_gen_college + schoolsup * studytime + schoolsup * first_gen_college,
##     data = ftrain)
##
## Coefficients:
##                                    Value Std. Error  t value
## failedyes                        -1.55916     0.2803 -5.56248
## gooutlow                          0.58202     0.2260  2.57501
## romanticyes                      -0.68049     0.2310 -2.94618
## schoolsupyes                      0.01527     0.8809  0.01734
## first_gen_collegeyes             -0.87441     0.2449 -3.56977
## studytime                         0.31024     0.1444  2.14898
## schoolsupyes:studytime           -0.89744     0.3472 -2.58483
## schoolsupyes:first_gen_collegeyes  1.78767     0.6142  2.91072
##
## Intercepts:
##                      Value   Std. Error t value
## Poor|Weak           -2.8407  0.4234    -6.7090
## Weak|Sufficient     -1.0846  0.3904    -2.7781
## Sufficient|Good      1.1195  0.3899     2.8716
## Good|Very Good       2.3538  0.4154     5.6661
## Very Good|Excellent  3.2057  0.4575     7.0075
##
## Residual Deviance: 873.2587
## AIC: 899.2587
```

```
(ctable <- coef(summary(mod6)))
```

```
##
## Re-fitting to get Hessian
```

```
##                                       Value Std. Error     t value
## failedyes                        -1.55915962  0.2802994 -5.56247945
## gooutlow                          0.58201779  0.2260254  2.57501100
## romanticyes                      -0.68048602  0.2309721 -2.94618281
## schoolsupyes                      0.01527404  0.8808503  0.01734011
## first_gen_collegeyes             -0.87441246  0.2449495 -3.56976600
## studytime                         0.31023730  0.1443649  2.14898050
```

```
## schoolsupyes:studytime            -0.89744352  0.3471959 -2.58483360
## schoolsupyes:first_gen_collegeyes  1.78767301  0.6141683  2.91072192
## Poor|Weak                         -2.84071658  0.4234218 -6.70895259
## Weak|Sufficient                   -1.08462029  0.3904224 -2.77806907
## Sufficient|Good                    1.11949859  0.3898567  2.87156458
## Good|Very Good                     2.35375515  0.4154121  5.66607292
## Very Good|Excellent                3.20565589  0.4574631  7.00746349
```

```
p6 <- pnorm(abs(ctable[, "t value"]), lower.tail = FALSE) * 2
(ctable <- cbind(ctable, "p value" = p6))
```

```
##                                       Value Std. Error     t value
## failedyes                         -1.55915962  0.2802994 -5.56247945
## gooutlow                           0.58201779  0.2260254  2.57501100
## romanticyes                       -0.68048602  0.2309721 -2.94618281
## schoolsupyes                       0.01527404  0.8808503  0.01734011
## first_gen_collegeyes              -0.87441246  0.2449495 -3.56976600
## studytime                          0.31023730  0.1443649  2.14898050
## schoolsupyes:studytime            -0.89744352  0.3471959 -2.58483360
## schoolsupyes:first_gen_collegeyes  1.78767301  0.6141683  2.91072192
## Poor|Weak                         -2.84071658  0.4234218 -6.70895259
## Weak|Sufficient                   -1.08462029  0.3904224 -2.77806907
## Sufficient|Good                    1.11949859  0.3898567  2.87156458
## Good|Very Good                     2.35375515  0.4154121  5.66607292
## Very Good|Excellent                3.20565589  0.4574631  7.00746349
##                                       p value
## failedyes                         2.659684e-08
## gooutlow                          1.002369e-02
## romanticyes                       3.217222e-03
## schoolsupyes                      9.861653e-01
## first_gen_collegeyes              3.573003e-04
## studytime                         3.163595e-02
## schoolsupyes:studytime            9.742600e-03
## schoolsupyes:first_gen_collegeyes 3.605948e-03
## Poor|Weak                         1.960263e-11
## Weak|Sufficient                   5.468299e-03
## Sufficient|Good                   4.084453e-03
## Good|Very Good                    1.461074e-08
## Very Good|Excellent               2.426773e-12
```

```
(ci5 <- confint(mod6))
```

```
## Waiting for profiling to be done...
##
## Re-fitting to get Hessian
```

```
##                                       2.5 %     97.5 %
## failedyes                         -2.11603937 -1.0156926
## gooutlow                           0.14100166  1.0278318
## romanticyes                       -1.13625714 -0.2299976
## schoolsupyes                      -1.71834716  1.7492857
## first_gen_collegeyes              -1.35840403 -0.3972182
## studytime                          0.02754372  0.5941023
## schoolsupyes:studytime            -1.58076549 -0.2136889
## schoolsupyes:first_gen_collegeyes  0.58713044  3.0005349
```

```
acc.ord6 <- predict(mod6, ftrain)
ctable <- table(ftrain$cat_g3, acc.ord6)
ctable
```

```
##             acc.ord6
##              Poor Weak Sufficient Good Very Good Excellent
##   Poor          3   10         20    0         0         0
##   Weak          5   22         46    0         0         0
##   Sufficient    2   13        113    2         0         0
##   Good          0    0         47    1         0         0
##   Very Good     0    0         17    0         0         0
##   Excellent     0    0         14    1         0         0
```

Still not very accurate for the training

Random forest:

```
library(randomForest)
rf.cat<-randomForest(cat_g3~. -G1 -G2 -G3 -ord_g3 -famsup -internet -Medu -Fedu,data = ftrain, mtry = 3
print(rf.cat)
```

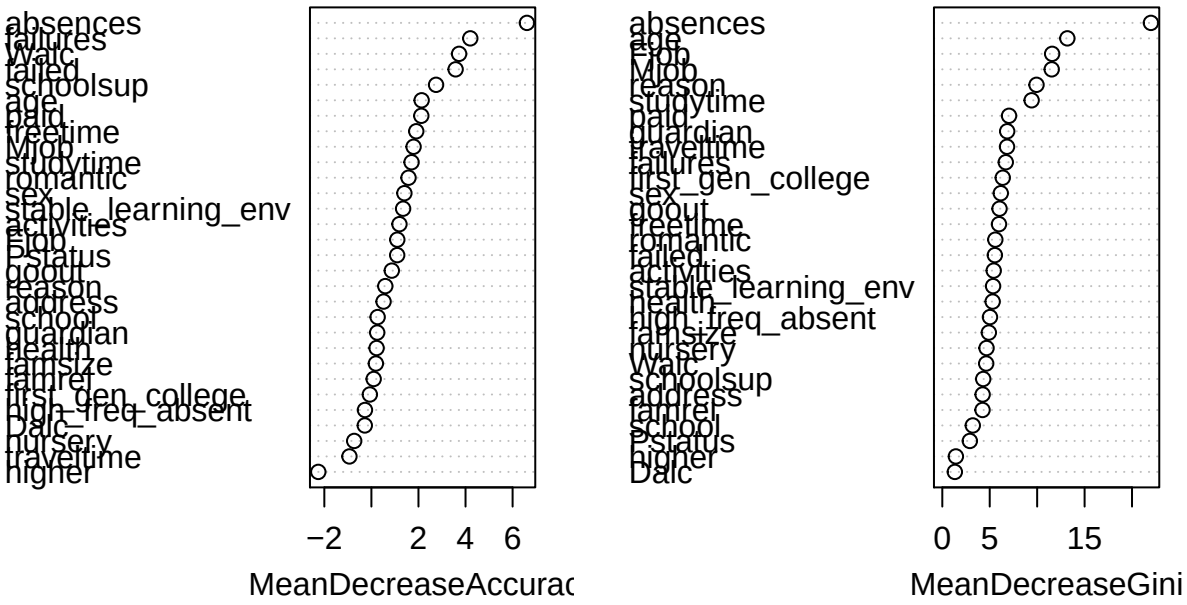
```
##
## Call:
##  randomForest(formula = cat_g3 ~ . - G1 - G2 - G3 - ord_g3 - famsup -      internet - Medu - Fedu, da
##                Type of random forest: classification
##                      Number of trees: 50
## No. of variables tried at each split: 3
##
##         OOB estimate of  error rate: 54.75%
## Confusion matrix:
##             Poor Weak Sufficient Good Very Good Excellent class.error
## Poor          13    6         10    4         0         0   0.6060606
## Weak           4   21         47    1         0         0   0.7123288
## Sufficient     3   26         93    7         0         1   0.2846154
## Good           1    4         27   16         0         0   0.6666667
## Very Good      0    2         11    4         0         0   1.0000000
## Excellent      2    0          9    4         0         0   1.0000000
```

```
importance(rf.cat)
```

```
##                             Poor       Weak   Sufficient       Good   Very Good
## school              -0.320418728  0.6070449  0.536586512 -1.4428269  0.00000000
## sex                  1.321702560  1.2749856 -0.122052653  1.5812640 -1.21718806
## age                  0.984597247  0.5038971  1.159981444  2.3881188 -0.58888483
## address             -0.472521387  0.2845834 -0.376090796  2.2375512 -1.44337567
## famsize              1.213980759 -0.3454637  0.607389361 -0.2252485 -0.06008635
## Pstatus             -0.182974457  1.6794783 -0.456855873  0.6459451 -1.01015254
## Mjob                 1.050310978  1.3624898  0.578356453  0.8604698 -1.01015254
## Fjob                -0.586613674  0.2987154  2.166906663  0.5657879 -0.77269072
## reason               0.978273274 -0.1708659  0.510657222  0.5323923 -0.40101903
## guardian             0.098663704 -0.3393417  0.497340949  0.6921399 -1.27911300
## traveltime           0.736400216 -0.5796042 -1.898571108  0.8062992  0.15264469
## studytime            0.267334741  1.2751827  0.456204621  1.8896889 -0.07246908
## failures             1.924065089  2.8254290  4.450136288  2.5971734  1.01015254
## schoolsup            0.821994937  2.7978591  0.504441187  2.9108767  1.01015254
## paid                 1.684780389  0.5080240  1.575191994  1.1912210  0.00000000
```

```
## activities           1.719215728 -1.3205812  1.966891245 -0.3324259  0.00000000
## nursery              1.090595541 -0.7405726 -1.453292937  1.1017746 -1.01015254
## higher              -1.708956419 -0.9839286 -1.875570124  0.0000000  0.00000000
## romantic             1.134563701  0.9470747  1.333690841  0.4796738 -0.74664271
## famrel              -0.059822305 -0.2275365  0.416721244  0.1300787  0.00000000
## freetime             1.003643613  0.7702195  2.480309233  0.9085181 -1.29533108
## goout                0.082645413  1.8258474 -1.109331234  0.2742068 -0.09408041
## Dalc                 0.000000000  0.1921850 -0.347365205  0.0000000  0.00000000
## Walc                 0.943356017  1.9493327  1.894423931  2.5095853 -0.57928445
## health               0.877127612  0.8338566 -0.007584328  0.6138841 -1.01015254
## absences             7.429952093  2.8645070  3.765008019  1.8803444 -0.94636583
## first_gen_college   -0.771407541  1.3272444 -0.613618638  0.8694877 -1.58437556
## stable_learning_env -0.006364394  0.2964398  0.839122326  1.8820237  0.59541114
## high_freq_absent     2.496021386 -1.4945068 -0.396938483  1.9728701 -1.44337567
## failed               1.009950567  4.1747041  0.011571816  2.8402935  0.00000000
##                      Excellent MeanDecreaseAccuracy MeanDecreaseGini
## school               0.00000000           0.26525145         3.214762
## sex                  0.66640053           1.40196316         6.166263
## age                  1.56608020           2.13426777        13.182885
## address              0.37262050           0.51646163         4.252106
## famsize              0.27756369           0.19064309         4.904742
## Pstatus              1.01015254           1.09596869         2.903965
## Mjob                 1.09521748           1.79230702        11.536026
## Fjob                -2.48942157           1.09993703        11.580290
## reason              -0.95321840           0.59019149         9.931110
## guardian            -1.44337567           0.24708010         6.839414
## traveltime           1.32240345          -0.93330351         6.822486
## studytime            0.39283710           1.70684300         9.419036
## failures             1.36646256           4.20180107         6.691546
## schoolsup            1.01015254           2.74823723         4.312787
## paid                -0.43274793           2.12035865         7.038314
## activities           0.23663289           1.19163361         5.421727
## nursery              1.01015254          -0.73074577         4.665362
## higher               0.00000000          -2.25615909         1.431254
## romantic             1.01015254           1.57717180         5.588819
## famrel               0.00000000           0.09648131         4.240872
## freetime            -0.55177701           1.90607489         5.977717
## goout               -0.40004167           0.86662440         6.034161
## Dalc                 0.00000000          -0.28075736         1.323301
## Walc                 1.01015254           3.72689747         4.628794
## health              -2.33080612           0.22093592         5.309311
## absences            -0.89171402           6.60829832        21.992281
## first_gen_college   -2.06447640          -0.06586174         6.373757
## stable_learning_env  0.57437745           1.34729174         5.352110
## high_freq_absent    -0.04677905          -0.27364388         5.025976
## failed               0.00000000           3.57839215         5.541088
```

```
varImpPlot(rf.cat)
```




```
rf.acc<- predict(rf.cat, ftrain, type = 'class')
t<-table(predictions=rf.acc, actual=ftrain$cat_g3)
t
```

```
##             actual
## predictions  Poor Weak Sufficient Good Very Good Excellent
##   Poor         33    0          0    0         0         0
##   Weak          0   73          1    0         0         0
##   Sufficient    0    0        129    0         1         0
##   Good          0    0          0   48         0         0
##   Very Good     0    0          0    0        16         0
##   Excellent     0    0          0    0         0        15
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.9936709
```

Very fitted model with accuracy for training data >99%.

Let's see what the accuracy rate for the testing set is:

```
rf.pred<- predict(rf.cat, ftest, type = 'class')
t<-table(predictions=rf.pred, actual=ftest$cat_g3)
t
```

```
##             actual
## predictions  Poor Weak Sufficient Good Very Good Excellent
##   Poor          1    0          1    0         0         0
##   Weak          1    2          2    0         0         0
##   Sufficient    3   15         28    8         2         1
##   Good          0    2          4    4         3         2
##   Very Good     0    0          0    0         0         0
```

```
##   Excellent     0    0          0    0         0         0
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.443038
```

43.03% accuracy, which is an improvement.

Let's choose the most important variables, as well as interaction effects we believe to be important based on previous exploration:

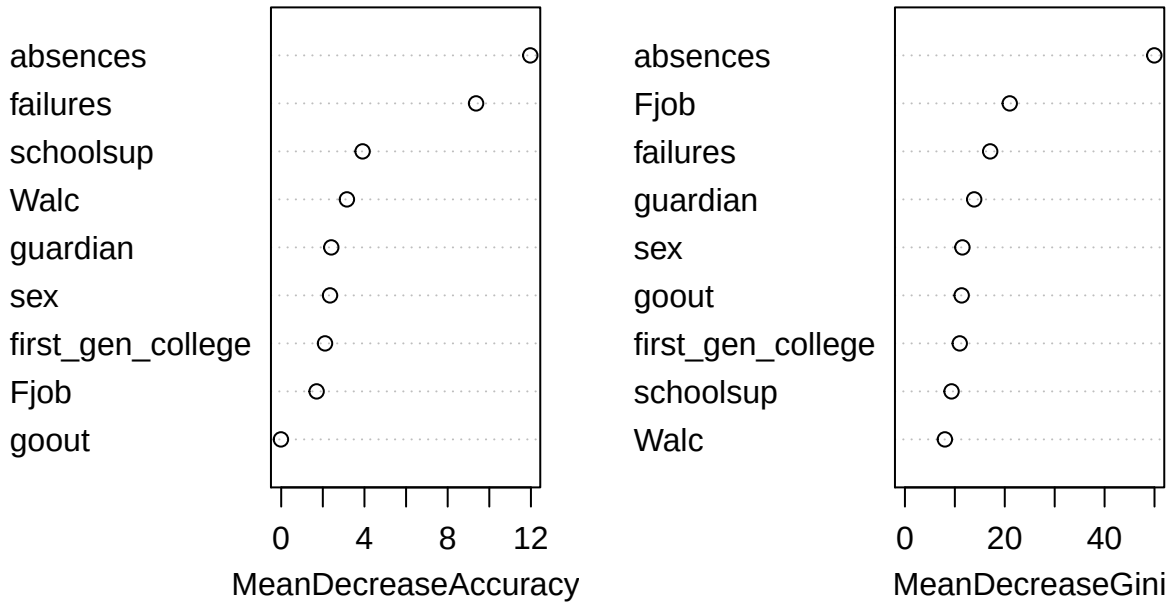
```
rf.cat1<-randomForest(cat_g3~failures + absences + sex + Walc + Fjob +goout + schoolsup + first_gen_coll
print(rf.cat1)
```

```
##
## Call:
##  randomForest(formula = cat_g3 ~ failures + absences + sex + Walc +      Fjob + goout + schoolsup + f
##                Type of random forest: classification
##                      Number of trees: 50
## No. of variables tried at each split: 3
##
##         OOB estimate of  error rate: 53.48%
## Confusion matrix:
##            Poor Weak Sufficient Good Very Good Excellent class.error
## Poor         22    1          5    5         0         0   0.3333333
## Weak          6   25         38    3         0         1   0.6575342
## Sufficient    6   22         82   16         2         2   0.3692308
## Good          2    3         25   16         0         2   0.6666667
## Very Good     0    1          8    6         2         0   0.8823529
## Excellent     1    1          7    5         1         0   1.0000000
```

```
importance(rf.cat1)
```

```
##                        Poor       Weak Sufficient       Good Very Good
## failures           8.6121328  6.0201756  1.4792393  4.2656905 1.7864740
## absences          15.9858895  3.2594679  4.2439674  3.4438647 4.8080359
## sex                4.1700548  1.7763578 -1.5818630  2.7253577 0.6958109
## Walc               1.7797308  1.4204901  0.5562847  3.8118579 3.1646330
## Fjob              -0.5493871  2.2420307  0.9393071 -0.6267721 2.4635622
## goout             -2.2153698  0.2026378 -1.7174705  3.5808755 2.5347286
## schoolsup          4.5863468  5.7378686 -2.2380494  4.0462053 0.6024591
## first_gen_college  3.8636921  0.6620441 -1.2973437  2.6361910 1.0563419
## guardian           1.0406191 -0.9826512  1.8111343  1.0331062 1.7901209
##                    Excellent MeanDecreaseAccuracy MeanDecreaseGini
## failures           1.3856633           9.36468682        17.078776
## absences          -1.9292776          11.96940757        49.954884
## sex               -0.9165469           2.34551886        11.514774
## Walc               1.7790961           3.15659358         8.005025
## Fjob               0.5692545           1.70143799        20.997210
## goout              1.0290664          -0.01344227        11.362590
## schoolsup          1.0101525           3.91085495         9.336974
## first_gen_college  0.9965123           2.10524475        10.979444
## guardian           1.0201957           2.40638614        13.872862
```

```
varImpPlot(rf.cat1)
```




```
rf.acc<- predict(rf.cat1, ftrain, type = 'class')
t<-table(predictions=rf.acc, actual=ftrain$cat_g3)
t
```

```
##             actual
## predictions  Poor Weak Sufficient Good Very Good Excellent
##   Poor         31    4          1    1         0         0
##   Weak          0   53          0    0         0         0
##   Sufficient    0   14        127   12         5         4
##   Good          2    1          1   35         3         2
##   Very Good     0    0          0    0         8         0
##   Excellent     0    1          1    0         1         9
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.8322785
```

54.75% OOB estimate of error rate and 83.5% accuracy rate for the training data.

```
rf.pred1<- predict(rf.cat1, ftest, type = 'class')
t<-table(predictions=rf.pred1, actual=ftest$cat_g3)
t
```

```
##             actual
## predictions  Poor Weak Sufficient Good Very Good Excellent
##   Poor          1    1          2    0         0         0
##   Weak          0    3          5    0         0         0
##   Sufficient    2   13         23    8         3         1
##   Good          1    2          5    3         2         2
##   Very Good     0    0          0    1         0         0
##   Excellent     1    0          0    0         0         0
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.3797468
```

37.97% Accuracy, which is less than the full RF model.

The RF models indicate that for grade categorization, the most important variables are absences, failed, guardian, studytime, Mjob and Fjob, schoolsup, age, goout, first_gen_college (not in that order).

## Recoding binary response variable for pass-fail

Considering final grades as a continuous variable and ordinal categorical variable gave poor results. Therefore, we'd like to model a binary variable that indicates whether the student passes (grade >= 10) or fails (<10).

```
data <- data %>%
  mutate(pf = case_when(
    G3 >= 10 ~ "pass",
    G3 < 10 ~ "fail"
  ))
data <- data %>%
  mutate(pf = factor(pf, levels=c("pass", "fail"), ordered = FALSE))

set.seed(3)
train_ind1 <- sample(x = nrow(data), size = 0.8 * nrow(data))
test_ind_neg1 <- -train_ind1
ftrain1 <- data[train_ind1, ]
ftest1 <- data[test_ind_neg1, ]
```

## Fitting a decision tree on pass-fail

```
library(tree)
```

```
## Registered S3 method overwritten by 'tree':
##   method     from
##   print.tree cli
```

```
library(rpart)
```

## Fitting random forest on pass-fail

Fitting with ALL predictors:

```
rf.bin<-randomForest(pf~. -G1 -G2 -G3 -ord_g3 - cat_g3 -Medu -Fedu,data = ftrain1,mtry=3, ntree=50, impo
print(rf.bin)
```

```
##
## Call:
##  randomForest(formula = pf ~ . - G1 - G2 - G3 - ord_g3 - cat_g3 -      Medu - Fedu, data = ftrain1, n
##                Type of random forest: classification
##                      Number of trees: 50
## No. of variables tried at each split: 3
##
##         OOB estimate of  error rate: 29.43%
## Confusion matrix:
##      pass fail class.error
## pass  184   26   0.1238095
```

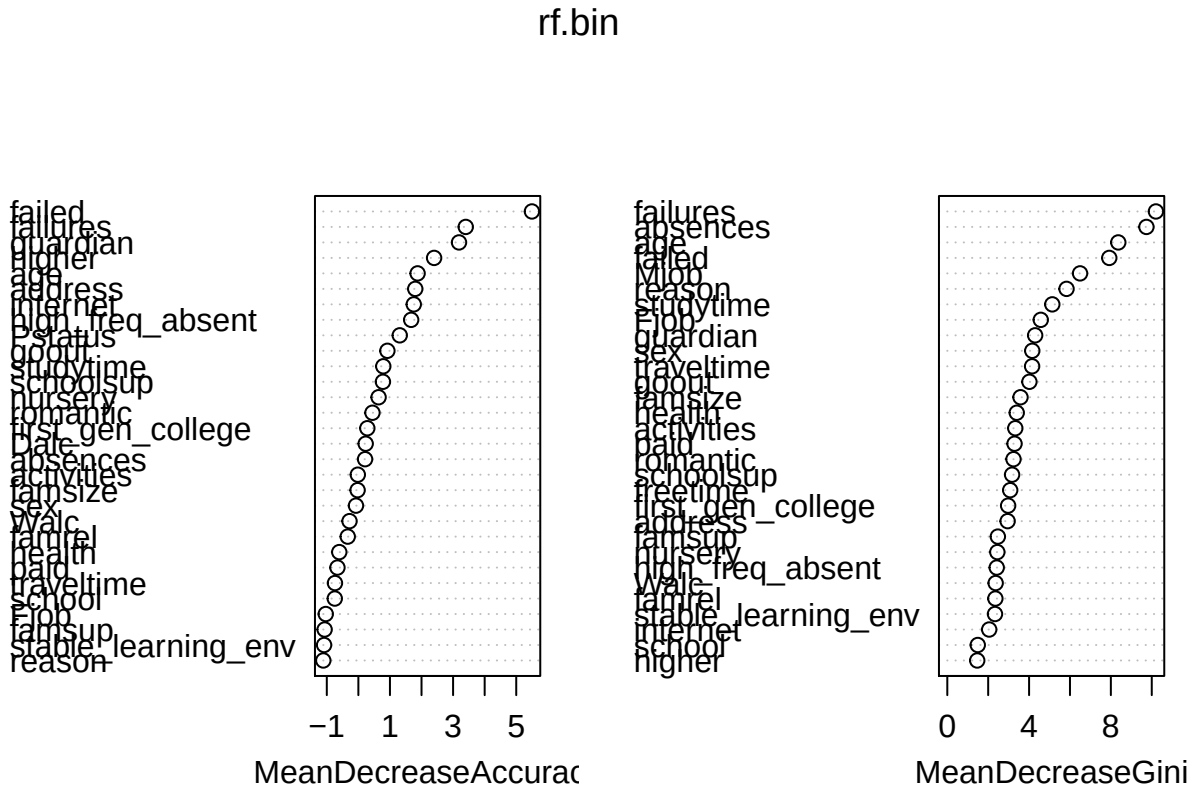
```
## fail   67   39   0.6320755
```

```
importance(rf.bin)
```

```
##                            pass        fail MeanDecreaseAccuracy
## school               -1.69539956  0.37885075          -0.74738177
## sex                  -1.45415821  2.13822688          -0.07567757
## age                   0.63011705  2.11381194           1.87619599
## address               1.27916395  1.21167706           1.80137118
## famsize              -0.24226406  0.29480951          -0.02478651
## Pstatus               0.71093417  0.99703008           1.31089736
## Mjob                 -2.09733608  1.31646571          -1.31266170
## Fjob                 -1.87755314  0.45522986          -1.03343744
## reason               -0.64952368 -1.40745713          -1.11103328
## guardian              2.62036387  1.66962303           3.18733604
## traveltime           -0.53631386 -0.67497964          -0.74197005
## studytime             0.10814464  1.24581101           0.78889593
## failures              2.72089585  3.45172072           3.40114891
## schoolsup             0.47395352  0.83923911           0.77785937
## famsup               -2.24448456  0.85412734          -1.06899815
## paid                 -1.69586713  0.69961695          -0.66307314
## activities            0.08870206  0.03485459          -0.01783894
## nursery               1.19263402 -0.37780255           0.63986267
## higher                2.37777330  1.63979375           2.39886887
## internet              0.26077282  2.34540344           1.75415359
## romantic             -0.56316200  1.32075190           0.44557551
## famrel               -0.47601829  0.24189993          -0.33689656
## freetime             -1.68415586 -0.26468897          -1.24724077
## goout                 0.89295545  0.68561404           0.91923597
## Dalc                  0.50488073 -0.30143072           0.23108292
## Walc                 -0.42407959  0.11218083          -0.28017793
## health               -0.17162726 -0.83811022          -0.60496417
## absences              0.80604415 -0.65793234           0.21187465
## first_gen_college    -0.55099145  1.03920297           0.28391785
## stable_learning_env -1.22271417 -0.23794931          -1.08628839
## high_freq_absent      1.88896693 -0.01516537           1.67227817
## failed                5.38268767  3.60544316           5.49713600
##                      MeanDecreaseGini
## school                       1.490173
## sex                          4.155664
## age                          8.363010
## address                      2.950986
## famsize                      3.580451
## Pstatus                      1.427602
## Mjob                         6.493687
## Fjob                         4.571916
## reason                       5.832141
## guardian                     4.296680
## traveltime                   4.147714
## studytime                    5.134898
## failures                    10.203794
## schoolsup                    3.168955
## famsup                       2.471933
## paid                         3.288568
## activities                   3.325554
```

```
## nursery                    2.446616
## higher                     1.463869
## internet                   2.048851
## romantic                   3.237635
## famrel                     2.351032
## freetime                   3.076328
## goout                      4.015702
## Dalc                       1.109252
## Walc                       2.365032
## health                     3.396389
## absences                   9.740021
## first_gen_college          2.975530
## stable_learning_env        2.331882
## high_freq_absent           2.417378
## failed                     7.922255
```

```
varImpPlot(rf.bin)
```




```
rf.acc<- predict(rf.bin, ftrain1, type = 'class')
t<-table(predictions=rf.acc, actual=ftrain1$pf)
t
```

```
##            actual
## predictions pass fail
##        pass  209    0
##        fail    1  106
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.9968354
```

Predictions on testing set:

```
rf.pred2<- predict(rf.bin, ftest1, type = 'class')
t<-table(predictions=rf.pred2, actual=ftest1$pf)
t
```

```
##            actual
## predictions pass fail
##        pass   50   20
##        fail    5    4
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.6835443
```

72.15% accuracy rate.

Finding the best random forest model by including important predictors:

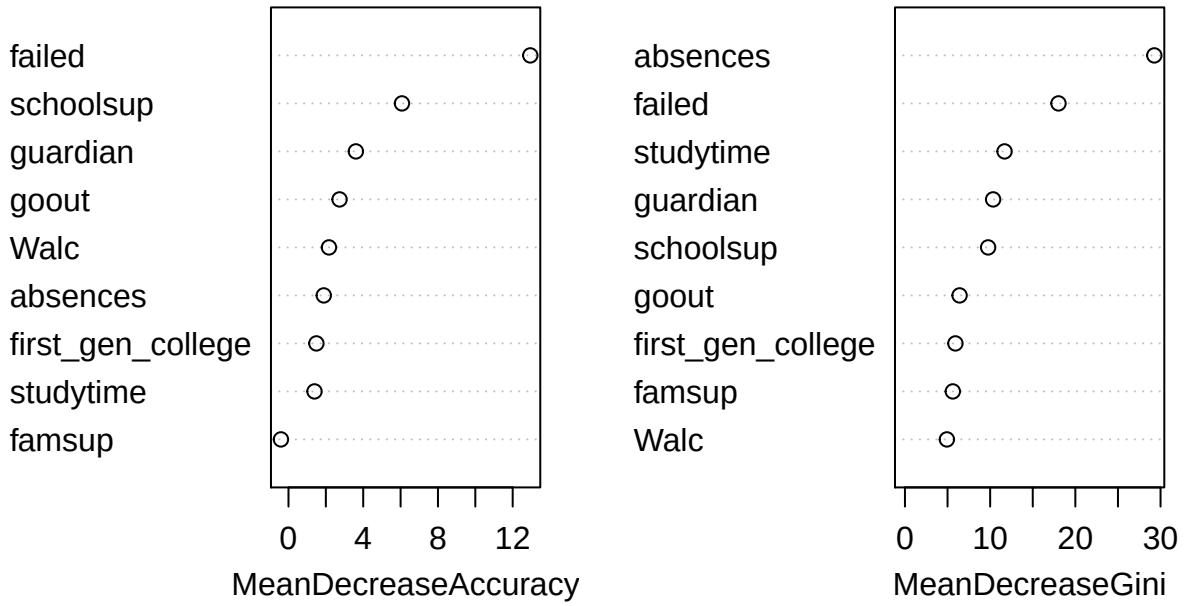
```
rf.bin1<-randomForest(pf~failed + absences+ guardian + studytime + goout + schoolsup + first_gen_college
print(rf.bin1)
```

```
##
## Call:
##  randomForest(formula = pf ~ failed + absences + guardian + studytime +      goout + schoolsup + firs
##                Type of random forest: classification
##                      Number of trees: 50
## No. of variables tried at each split: 3
##
##         OOB estimate of  error rate: 28.8%
## Confusion matrix:
##      pass fail class.error
## pass  184   26   0.1238095
## fail   65   41   0.6132075
```

```
importance(rf.bin1)
```

```
##                        pass       fail MeanDecreaseAccuracy MeanDecreaseGini
## failed            10.7389547  9.6063928           12.9429808        18.022236
## absences           1.6714305  0.8186185            1.8880334        29.270396
## guardian           3.4076194  1.0696011            3.6062988        10.347955
## studytime          0.3992517  1.6308742            1.3923129        11.691041
## goout              2.0026476  1.7536215            2.7330909         6.411513
## schoolsup          3.1041935  6.0665836            6.0734059         9.764057
## first_gen_college  1.4482848  0.2376860            1.4935446         5.923239
## Walc               0.7259123  2.9669210            2.1669777         4.922156
## famsup             0.7347495 -1.6619282           -0.4042212         5.617372
```

```
varImpPlot(rf.bin1)
```




```
rf.acc1<- predict(rf.bin1, ftrain1, type = 'class')
t<-table(predictions=rf.acc1, actual=ftrain1$pf)
t
```

```
##            actual
## predictions pass fail
##        pass  208   28
##        fail    2   78
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.9050633
```

The pared-down model has an 00B estimate of error rate of 25.95% and a training set prediction accuracy rate of 90.19%.

Predictions on testing set:

```
rf.pred3<- predict(rf.bin1, ftest1, type = 'class')
t<-table(predictions=rf.pred3, actual=ftest1$pf)
t
```

```
##            actual
## predictions pass fail
##        pass   49   18
##        fail    6    6
```

```
sum(diag(t))/sum(t)
```

```
## [1] 0.6962025
```

72.15% prediction accuracy rate.

Overall the random-forests for pass-fail indicate that the most important factors affecting whether the student passes/fails are failed, absences, guardian, studytime, goout, schoolsup, first_gen_college.