**Introduction Section**

1. **Provide details regarding the question you want to address.**

* Goal of this report is to study the relationship between interim STA302H1 quiz scores (quiz 1 – 3 scores), study time (weeks 1 – 4), and COVID contemplation time (week 1- 4), vs. final STA302H1 quiz score (quiz 4 score).
* Studies show individual relationship effects
* TODO: Studies show positive correlation b/w consecutive weeks of study and quiz scores
* TODO: Studies show times of high anxiety (e.g., COVID) and illness, quiz scores decrease
* My paper studies all these covariates together to examine collective effect on quiz performance AND effects of covariates on each other (hence the interaction terms)
* Population:
  + Online accelerated Summer 2021 STA302H1 cohort
  + n = 227 students at the beginning of the course
  + n = 198 students as of August 13, 2021
* Professor surveyed students (all short answer) on Quercus for the first 4 weeks of STA302H1:
  + End of Week 1 (July 5 – July 9)
  + End of Week 2 (July 12 – July 16)
  + End of Week 3 (July 19 – July 23)
  + End of Week 4 (July 26 – July 30)

1. **What is the purpose of developing this model?**

* We want to determine the strongest predictors of quiz 4 score:
  + interim STA302H1 quiz scores,
  + study time,
  + COVID contemplation time,
  + Country of origin, or
  + some other combination of terms

1. **How does the model meet the purpose of your model?**
   * Current professors can identify possible weak topics, reflect on things they did/did not help students, and tailor their future lessons that way
   * Teaching stream professors can devote resources to developing carefully curated course content for material students find most challenging (based on quiz scores)
   * Future professors can establish reasonable course expectations, and identify common conceptual pitfalls so they can prepare extra well for those lecture
   * Current students can focus on key material to getting high grades on hard quizzes
   * Future students can establish reasonable expectations about workload and develop strategies to maximize their time and success in STA302H1 with available resources
2. **Explain how you’ll develop the model (without stating any model results).**

**For example, you could:**

* 1. **Take mean of 3 quiz scores, weeks 1 – 4 COVID, weeks 1 – 4 STA302H1 study**
  2. **Take median of 3 quiz scores, weeks 1 – 4 COVID, weeks 1 – 4 STA302H1 study**
  3. **Analyze similar countries separately or add country as a predictor variable and group similar countries together to reduce number of categories.**
* Manually reformat data instead of reformatting programmatically, since very few errors
  + Remove “hours” by casting to double
  + Remove non-Unicode characters “<UTF-098>”
  + Capitalize “canada” and “china” so they’re treated as the same country as “Canada” and “China”
  + Rearrange columns, group COVID times, study times, and quiz scores together
* Handle missing data (entries containing NA).
  + Missing the country is OK
    - just mark country as unknown
  + Missing any number of COVID and STA302H1 hours is OK
    - Those students either forgot or abstained from sharing because they felt uncomfortable sharing it.
    - Missing COVID or STA302H1 hours alone is no reason to exclude them from the dataset. They might still write quizzes though.
  + Identify the number of quizzes students miss.
    - 1 – 2 NAs for quiz scores is OK
      * Some STA302H1 students join late from the waitlist.
      * The new “best 3 of 5” quiz marking scheme allows students to miss at most 2 quizzes without penalty.
    - 3 – 4 NAs indicates the student dropped STA302H1
      * Students who chronically skip quizzes are usually not committed to (e.g., have given up on) completing STA302H1, and are highly likely to drop STA302H1 anyways
      * Quiz marks are worth a substantial portion of one’s STA302H1 grade, so a low quiz grade may jeopardize students from getting an A in STA302H1
* Identify influential outliers
  + Consider removing students with missing Quiz 4 scores?
  + No amount of transformation or recentering can correct outliers
* Create descriptive statistics
  + Create histograms to analyze frequencies of COVID time intervals, study times and quiz scores, not grouped by country, analyzed data as a whole
  + Create boxplots separated by country to visualize the 5 number summary (Q1, median, Q3, min, max)
  + Create 5-number summary statistics to calculate median and mean to go with the histograms and boxplots
* Create pair scatterplot to get a bird’s eye view on all possible relationships, we’ll examine ones with interesting relationships more closely
* Use model selection criterion to determine reasonable model
  + Create correlation matrix to find correlation between two variables, use these to derive first few terms in model
  + Consult empirical research as well to derive new terms for final model.
* Model diagnostics used to verify assumptions of the final model
* Multicollinearity among predictor variables assessed using VIF, correlation matrix.
  + Partial residual plots used to examine linearity among numerical variables.
* Recentering used to reduce multicollinearity?
  + Reducing multicollinearity helps us determine which terms should be highly correlated.
* Transformations to reduce skewness of model? 🡨 why do this?

**Exploratory Data Analysis**

1. **Give a detailed description of the variables in the dataset.**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Meaning** | **Type of Variable** |
| Country | Student’s country of origin | Categorical/nominal |
| Quiz\_1\_Score | Student’s quiz 1 score, out of 10 | Continuous numeric |
| Quiz\_2\_Score | Student’s quiz 2 score, out of 10 | Continuous numeric |
| Quiz\_3\_Score | Student’s quiz 3 score, out of 10 | Continuous numeric |
| Quiz\_4\_Score | Student’s quiz 4 score, out of 10 | Continuous numeric |
| COVID..hours.W1 | Time student spent thinking about COVID-19 during Week 1, in hrs | Continuous numeric |
| COVID..hours.W2 | Time student spent thinking about COVID-19 during Week 2, in hrs | Continuous numeric |
| COVID..hours.W3 | Time student spent thinking about COVID-19 during Week 3, in hrs | Continuous numeric |
| COVID..hours.W4 | Time student spent thinking about COVID-19 during Week 4, in hrs | Continuous numeric |
| STA302..hours.W1 | Time student spent studying for STA302H1 during Week 1 (can include lecture time, review time, quiz time, or assignment time) | Continuous numeric |
| STA302..hours.W2 | Time student spent studying for STA302H1 during Week 2 | Continuous numeric |
| STA302..hours.W3 | Time student spent studying for STA302H1 during Week 3 | Continuous numeric |
| STA302..hours.W4 | Time student spent studying for STA302H1 during Week 4 | Continuous numeric |

* Response variable:
  + Quiz 4 score (out of 10) 🡨 performance on quiz 4, numerical ratio variable
* Predictor variables:
  + Quiz\_1\_Score, … , Quiz\_4\_Score = grades on quiz 1 – 3 scores (out of 10) 🡨 numerical ratio, not necessarily numeric

1. **Display appropriate tables or figures that highlight certain characteristics of your variables that you deem important to mention. Report results as is without further analysis, and display R output of results of model and place R code snippets in Appendix.**

* Display histograms of all predictor variables against quiz 4 score
* Display boxplots of all predictor variables against quiz 4 score
* Numerical values were summarized with mean and SD for normally distributed variables, median and IQR numerical variables for skewed variables
* Display pair scatterplots of relations between quiz 4 score and each predictor variable
* Display correlation matrix
* Display lm() output of linear model in nice table using gtsummary()
* Point out similarities and differences between various descriptive statistics (i.e., histograms, boxplots, scatterplots)
* Comment on distribution of variables
* Comment on 5-number summary (mean, mean, IQR), outliers across all countries – analysis will be performed later to find influential outliers
* TODO: Consult 3 – 4 external sources to confirm your findings.

**Model Development Selection**

1. **Give a detailed description of the process used to come up with the final model.**

* Find influential outliers in original dataset, before creating first model
  + TODO: Use Cook’s distance and leverage points to find influential outliers?
  + TODO: Use VIF method to find influential outliers?
  + TODO: Use DDFITS, DDBETA to find influential outliers?
  + no influential outliers -- no points outside of cook's distance in upper right and lower left quadrants of plot, so no points to remove.
    - no leverage points/influential points, so no points removed
* How you derive each term in your model, significant or otherwise
  + Visually inspecting the correlation matrix
    - Find correlation between two covariates
    - Find correlation between covariate and response variable
    - Pick highly correlated combinations of predictor variables (correlation >= 0.50 are considered) from correlation matrix as a heuristic for determining most significant terms in model
  + Visually inspect the pairs scatterplot to determine observed relationship (e.g., none, linear, quadratic, log, sqrt, etc.)
    - Quiz 4 ~ Quizzes 1 – 3 🡨 looks more (negative) quadratic than linear
    - Quiz 4 ~ Weeks 1 – 4 COVID-19 🡨 looks more (positive) quadratic than linear
    - Quiz 4 ~ Weeks 1 – 4 STA302H1 🡨 looks linear? Or no relationship?
    - For each of the three models, there should be about 8 (2^3) – 16 (2^4) possible models to choose from
    - TODO: how to do “least squares” on logarithmic, root functions? Does this fall under general linear models?
  + Initial model: fitted using quiz 4 as the response variable; and quiz1, quiz2, quiz3, covid1, covid2, covid3, covid4 (including 3 quadratic terms), 8 interaction terms, and country as predictor variables.
  + TODO: See figure X below for R output in appendix.
* Refine original model
  + Use backwards selection to remove insignificant terms (p-value >= 0.05) and find subset model with lowest AIC value (AIC = 136.06)
    - Final model: fitted using quiz 4 as the response variable; quiz3, interaction terms covid1\*covid2, covid2\*covid3, covid3\*covid4.
    - See figure X below for R output in appendix.
    - All further analyses were performed on the final model.
    - TODO: include AIC values in appendix.
  + Other model selection criteria to cross-reference:
    - R^2, adjusted R^2, C, AIC, forward selection
  + TODO: In the event of multiple best models, use testing set to break ties. Usually, one model tends to perform better
* State how you transformed your data
  + Think about interaction terms & multicollinearity
  + Correct multicollinearity with recentering, and perform analysis based on recentered model – undo transformation to reveal true relationship
  + Correct skewness with variable transformation, and perform analysis based on transformed model
* Report results of multiple regression model
  + TODO: Show ANOVA output in nice table
    - What variables are significant/insignificant at 5% significance level
      * If interaction terms are significant, not an additive model
      * Do interaction terms change the way you interpret model?
    - F-statistic – significance of overall model
    - P-values and T-values of individual variables, global P-value
    - Residual standard error
  + Explain results
    - State R^2 values, what they mean ("x% of the total variation in quiz4 can be explained by all variables in the model")
    - adjusted R^2 = R^2 adjusted for future fitted values.
* Interpret coefficients of each variable
  + For non-interaction terms, you could say: “for every unit increase in X, there is a y increase in Y…”
  + For interaction terms, you could say: “there exists an interaction effect between consecutive study weeks X1 and X2.”

1. **Add statistical and empirical justifications for your model.**
   1. **Examples of Statistical Justifications:**
      * **Checking Gauss-Markov assumptions**
      * **Using prior knowledge (e.g., quiz grades tend to be left skewed because few STA302H1 students fail quizzes)**
      * **Statistical theory from STA302H1 or STA248H1**
   2. **Examples of Empirical Justifications:**

* **Showing residual plots**
* **Showing skewed histograms**
* **Showing well fitted qqplots**
* Verify linear model assumptions by stating how you’ll test each assumption
  + A1: Linearity
    - To check this, examine scatterplot itself
  + A2: Independence of errors
    - To check this, examine scatterplot of residuals vs. fits for all predictor variables, state that there should be no discernable relation
  + A3: Homoscedasticity (constant variance)
    - To check this, examine scatterplot of residuals vs. fits – show there’s no megaphone effect or bowtie effect
  + A4: Normality of errors
    - To check this, show points follow line closely in qqplot
    - Also acceptable: Show histogram of residuals for approximate normality or use CLT for large sample size (n = 199 I think?).
* Report results of each assumption, along with residual plots, res. vs. fit, qqplot, location-scale plot, histogram of residuals
* model obeys A1: model has only linear terms and interaction terms, and
* we showed that all predictor variables show randomness when regressed with residuals.
* model obeys A2: random sample = assume errors are independent, and see 1st plot (residual vs. fitted plot)
* model obeys A3: approximately homoscedastic, from scale location plot, we see random scattered points about red horizontal line (mean?)
* model obeys A4: approximately normal -- slightly more left skewed (qqplot) than right skewed
* TODO: Insert R code to produce residual plots in appendix.

1. **Add in-depth diagnostics to illustrate the goodness of the model.**

* Validate model soundness
  + 55/45 split between training and testing 🡨 should have used 50/50 split
    - Check if mean of residuals = 0
      * Mean of residual close to 0 is still good enough
    - Check if histogram of residuals is approximately normal distributed
      * It is, by CLT (n = 199)
  + Perform t-tests on residuals to see if mean of residual = 0
    - Hypothesis:
      * H0: mean = 0
      * H1: mean != 0
    - Results:
      * t-value = -0.26242
      * p-value = 0.7938
        + need p-value < 0.05 to reject H0 (mean != 0)
      * 95% CI for mean resdiuals: (-0.4510668, 0.3462948)
        + 0 is in CI 🡨 fail to reject H0 (mean = 0)
  + Find 95% CI for each (numerical) predictor variable
    - lm() output already tells you whether they’re significant (whether or not to reject H0) 🡨 p values should be < 0.05

**Conclusion**

1. **Explain why model is useful in the context of the data.**

* Recall that the purpose of the model is to see whether previous quiz scores, time spent thinking about COVID, and study time can predict future quiz scores.

1. **Interpret final model in non-technical language (i.e., explain how the variables work, discuss predictions)**

* The model suggests strong evidence of a relationship between:
* Quiz 3 score: positive relationship
  + Quiz 3 is closer to quiz 4 in difficulty because students are used to online Quercus quiz format
  + Better understanding of rounding rules
  + Students study more for quizzes to better prepare for them
* (STA302W1, STA302W2), (STA302W2, STA302W3), (STA302W3, STA302W4) covariates: increase in study times between consecutive weeks (W1 -> W2 -> W3 -> W4): positive relationship
  + It seems like studying earlier on in STA302H1 has the most impact on final grades, rather than studying later in the semester.
  + Studying last minute is not effective (mass learning) compared to studying throughout the term (spaced learning).
  + With spaced learning, your knowledge has time to “compound.”
* Ceteris paribus, keeping all other variables constant.

1. **Is the model generalizable? If not, discuss any limitations/problems remaining with the model, and how they might impact its use in the real world.**

* Not really.
* Only generalizable to online courses, not in-person courses
* Students may be in different time zones (by country)
* 3rd year courses tend to perform better in general (data 3rd year students tend to study more and fail less than 1st student)
* Missing predictor variables such as…
  + Anxiety levels
    - TODO: Studies show high anxiety impairs course performance
    - TODO: Studies show high anxiety and more COVID think time
  + Numbers of hours of sleep
    - TODO: Studies show moderate sleep improves course performance
  + Number of hours of physical activity
    - TODO: Studies show moderate exercise improves course performance
* Despite of these limitations, further research may help inform us on benefits of study and COVID think times vs. quiz scores.

Limitations of Model

* Missing data
  + presence of NA values
  + remove 28 dropped students, missing other survey data (country, covid hours, study hours)
  + outliers?
* Sample size is roughly n = 200 people
  + Excludes students who dropped STA302H1
  + Blank entries and imputations for missing survey responses and missing quiz scores due to some students skipping quizzes
* R2 and adjusted R2 are relatively small.
  + Maybe we could use a different model to improve R2 and adjusted R2 values?
* Time spent in STA302H1 during weeks 3 – 4 includes completing the mini assignments
  + This explains why Weeks 3 – 4 STA302H1 study times may be slightly inflated

1. **(BONUS) Suggest ways to improve your model.**

* Take median of 3 quiz scores?
* Take median of weeks 1 – 4 COVID hours?
* Take median of weeks 1 – 4 STA302H1 study hours?
  + I can grab means and medians from the boxplots.
  + Median is less prone to skew than mean.
* Introducing compositive variables in model
  + e.g., anxiety + COVID + physical activity = happiness index
* Perhaps use empirical research to propose some more new terms to improve model

Possible model improvements

* Covid = high stress
* Hours of sleep = predict stress + quiz grades
* Add country back to predict time zone = sleep schedule = hours of sleep (in original data, Mongolia was only significant country)
* Social time = might increase study time, reduces covid time,
* Physical activity = predict stress + increase study time + reduce covid time (cite studies)
  + Read title scholastic paper and cite, don’t read whole thing, introductions
* ~~Large sample size?~~ n = 199 is a good enough sample size

Things My Model Doesn’t Account For -- Many factors can affect quiz 4 score

* Internal factors within STA302H1 (things that directly benefit STA302H1 grades)
  + Studying
  + Attending lectures
  + Attending office hours
  + Completing assignments
  + Completing readings
* External factors outside of STA302H1 (things that indirectly benefit STA302H1 grades)
  + Prerequisite knowledge
    - Prior background – direct (past stats/ML courses) or indirect (quantitative background, programming background)
  + Those who are more familiar with prerequisite statistics material and do well in prior courses have an easier time studying for STA302H1 and are more likely to succeed – ceteris paribus.
* Current work ethic, discipline, diligence
  + Exercising discipline allows one to consistency interact with STA302H1 material and increase their chances of retaining the material and performing well in STA302H1 assignments and quizzes.
* One’s disposition towards school
  + Those who are keen in school tend to perform better than disengaged students, regardless of class format, and vice versa
* One’s disposition about COVID
  + Positive thoughts can help tune out some negative COVID-19 thoughts and focus on what you have control over. Persisting COVID-19 thoughts can cause one to feel despair and pessimism
  + COVID case counts and current COVID restrictions in country of origin? 🡨 can be inferred from Country of origin
  + COVID-heavy countries tend to require more social distancing and public has greater anxiety over contracting COVID-19
* Hawthorne effect: students have an incentive to abstain or be dishonest to appear socially desirable 🡨 this goes in limitations
  + 3rd year students tend to be more committed and serious, so effect is minimal
* TODO: Do grade adjustments count? 🡨 Worth briefly mentioning
  + professor can choose to adjust grades to compensate for low mean quiz scores
* Learning environment
  + Online offerings are different from equivalent in-person offerings of STA302H1
    - More discipline necessary to succeed
    - More technological literacy required to succeed
      * online courses privileging students who have access to computers or the internet
      * some families are too poor to afford computers and internet, and must share computers or use public computers
    - Performance has more room to fluctuate – some people may prefer online courses over in person lectures due to long commute times, and vice versa, increased independence skills, etc.
    - Some people find it harder to create boundaries with work/rest, and work environments vs. play/sleep environment
* Social connections
  + Staying connected helps stave off negative COVID-19 thoughts and promote community
  + Fewer opportunities for study partners = less motivated to work on STA302H1
* Number of hours slept, quality of sleep
  + Well-rested brains tend to respond quicker, can better regulate their mood, have an easier time focusing during lecture, and make fewer mistakes on quizzes and assignment (or notice them more easily and readily)
* Number of hours spent doing physical activity (exercise helps brain learn, which may improve performance)
  + Exercise and physical activity make you more alert, less prone to illness and injury, promote a positive attitude, and improves relationships with other people
* Time spent away from STA302H1 (studying for quizzes, attending lectures, and doing assignments)
  + Number of professional activities (e.g., preparing for job interviews, holding a job, TA duties, research duties)
  + Number of recreational activities (e.g., going outside, biking, etc.)
    - Alternatives for STA302H1 studying, effects are debatable depending on how related they are to STA302H1 or statistics in general
  + Caring for family
    - Family responsibilities may distract or interfere with one’s progress on STA302H1 assignments and consume STA302H1 study time
    - Family members may also provide a nurturing environment for your studies through quality family time, strong family values, and family work connection
* Commute times
  + Increased commute times increases students stress levels because it leaves less time available for STA302H1 and other courses, and affects one’s disposition towards class format (in-person vs. online)
* Anxiety levels?
  + Anxiety may influence quiz scores and assignment performance because it affects cognitive performance – brain may hyperfocus (fixation) or hypofocus (distraction) – fight or flight, focus on survival (not dying of COVID-19) rather than thriving (succeeding in STA302H1)
* Mental health
  + Better mental health = more resilient individuals, more positive outlook on life, more altruistic
* Time zone 🡨 can be inferred from country of origin
  + Time zone may influence sleep schedule, may be trickier to coordinate group projects and multi-person assignments
  + One upside with working with teammates in opposite time zones is that someone is always working on the final project
* Chronotypes
  + Students in other time zones may alter their chronotypes to accommodate STA302H1, which may offset adverse effects of sleep loss on performance.