MA223 Engineering Statistics (Winter)

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Rubric for Class Questions

Questions in this class can feel overwhelming at times because computation is de-emphasized. So, instead of "solving" problems, we are often responding to open-ended questions. Essay (or "short answer") questions can be particularly challenging because a part of you feels like writing a book report and "throwing up on the page" (stating every vocab word you have ever heard of in hopes of saying something close to the right answer for enough credit) and keeping it short and sweet when you think a single sentence explains your thoughts. Fundamentally, an instructor can only grade what you communicate, and a large part of this class is communicating abstract concepts. There are different things that need to be communicated based on the type of question. Therefore, this page provides a guide both in how your questions will be graded but also in how to best answer those questions without throwing up on the page. The page is divided by the type of question that you might be asked.

Computation Questions:

Computation questions are those which ask you to provide a value (or set of values), using the computer to produce the values.

- The appropriate value is provided.
- Relevant computer code/output should be provided (or a sufficient justification of the steps performed by hand to reach the value requested).
- The value requested must be highlighted in the output or restated. For example, if there are multiple p-values in the output, you should indicate which p-value addresses the question posed.
- If applicable, the value provided must adhere to any conditions you were told to impose on the analysis.
- If necessary, state any conditions that you believed were unreasonable but must be assumed in order to carry out the analysis provided. This is only necessary when you are not told what assumptions to make.
- You may not use key statistical terminology discussed in class inappropriately.

Graphical Summary:

Graphical summaries are when we request the raw data be summarized appropriately.

- The graphic provided addresses the question of interest.
- The x-axis is clearly labeled.
- The y-axis is clearly labeled.
- The legend has clear labels.
- If requested, provide a description of the graphic:
  - The description should state the *story* the graphic is telling. You should **not** state the type of graphic or generalities about graphics of this nature. Instead, in the context of the problem, what is the graphic telling you about the data.
  - Descriptions can discuss trends in location, spread, or shape (any aspect of the distribution), but should focus on the primary question of interest if one exists.
- You may not use key statistical terminology discussed in class inappropriately.

Definition/Identification Statements:

Definition/Identification statements are those which ask you to identify some component of the problem (e.g., the population, the parameter, the test statistic from the provided output, etc.).

- If a value is requested, the value must be correctly identified.
- If a definition is requested, the definition must accurately reflect the technical definition and not include inaccurate statements.
- If you are to identify a component of the context (population, parameter, etc.), the component must be accurately defined without leaving out (or adding in) details that would fundamentally change the scope of the problem.
- Additional notes on parameters:
  - If requested, an appropriate symbol that will represent the parameter should be stated.
  - The parameter should be defined in the context of the problem.
  - Information about measurement units should be given if known.
- Additional notes on variables:
  - If multiple variables are requested, be sure to denote the role of each (response, factor, block, predictor, extraneous, etc.).
  - Information about measurement units should be given if known.

- You may not use key statistical terminology discussed in class inappropriately.

Hypotheses:

Hypotheses are the mathematical translation of the question of interest.

- Unless previously defined in another problem, all mathematical symbols must be defined.
- Unless previously defined in another problem, the parameter must be defined/present within the hypotheses.
- The correct equality term within the null hypothesis must be used.
- The correct strict inequality within the alternative hypothesis must be used.
- The hypotheses must accurately reflect the question of interest.
- You may not use key statistical terminology discussed in class inappropriately.

Description of Data Collection Procedure:

These questions ask you to describe the procedure used to collect data (typically on a lab assignment).

- Describe the procedure that was used to create each observation/case within the collected dataset (how each measurement was obtained).
- State how many observations/cases you collected.
- Provide adequate detail so any reader could recreate your collection scheme.
- Describe "best practices" you implemented to cerate a dataset representative of the population of interest.
- If requested, describe the limitations of your study:
  - Describe a limitation of the study design (something that could be improved in a future study).
  - A limitation is not a source of variability (it is not a reason why observations vary from unit to unit).
  - Sample size is not an acceptable response.
- You may not use key statistical terminology discussed in class inappropriately.

Model for Data Generating Process:

These questions ask you to provide a model for the data generating process using mathematical notation.

- All variables should include an index.
- Parameters should not include an index but should include a subscript for identification, if necessary.
- Any variable which is not obvious (such as x_i or indicator variables) should be defined.
- An error term should always be included, with an index.
- You may not use key statistical terminology discussed in class inappropriately.

Conclusions:

Conclusions are those questions that ask you to address a research question using the data or state what can be stated as a result of the analysis.

- A statement about whether there is "evidence" to support the alternative or not (or whether a statement is "reasonable" depending on the question).
- The statement must be **in the context of the problem**. That is, do not use statistical jargon ("reject the null hypothesis") or mathematical symbols (even if previously defined).
- "Evidence" (if applicable) must be supported by citing a p-value or confidence interval.
- "Reasonable" (if applicable) must be supported by citing a confidence interval.
- The p-value (or confidence interval) must be appropriately applied.
- A statement must be given how the p-value or confidence interval was used to reach the conclusion.
- You may not use key statistical terminology discussed in class inappropriately.

Assessing Conditions:

Assessing conditions (which occurs during the latter part of the term) asks you to determine if a particular condition is reasonable to assume.

- If a graphic is appropriate and requested, the graphic must adhere to the requirements of a Graphical Summary.
- A statement indicating whether the data is consistent with the condition or not is made (unless **extremely** obvious, this statement need not agree with the instructor).
- A statement about what you observed in the graphic (or context if a graphic is not appropriate).
- A statement about what you expected if the data were consistent with the condition.
- The response has consistent logic.
- If asked to assess all conditions, then each condition must be stated and assessed.
- You may not use key statistical terminology discussed in class inappropriately.

Justification Questions:

Justification questions are those other open-ended questions that ask for a "justification" or "explanation." These generally ask you to agree/disagree with a statement or answer a question and then justify your position.

- The response should answer the question posed.
- The response should supply relevant facts from the context.
- The response provides implications of those facts based on the course content.
- The response links implications to the answer.
- The response does not include irrelevant facts.
- The response uses logic which is correct.
- You may not use key statistical terminology discussed in class inappropriately.

In order to ensure your written solutions address the above requirements, it is helpful to keep in mind the following guide (illustrated early on in class) regarding how to approach such questions:

1. Sentence 1: answer the question.
2. Sentence 2: supply the appropriate facts from the context.
3. Sentence 3: discuss the implications of these facts and how they lead to the answer.

Edit Questions:

Edit questions are those in which an incorrect statement has been given and you are asked to correct the statement.

- The correction provided must exceed negating the current statement.
- The correction must result in an accurate statement.
- The correction must accurately reflect the intent of the original statement (what the person was trying to say but messed up).
- The correction must not include inaccurate components.
- You may not use key statistical terminology discussed in class inappropriately.

Multiple-Choice Questions:

Multiple-choice questions are those for which you are asked to select your answer from a pre-specified list of choices, and no justification for your choice is required. These questions are used when there are only a limited possible set of responses that could be provided, but often the difference between the provided responses is subtle.

- If only a single answer is correct, the correct answer must be chosen.
- If the question is a "select all that apply," then all appropriate answers must be selected, and no incorrect answers should be selected.

Rubric:

Every question will be graded according to the above specifications. Essentially, if the specifications are met, and the answer provided is correct, you have "successfully completed" the question; otherwise, you have not.

Answering questions under this framework requires you to adjust your mindset. Your goal is not simply "get as many points as possible" as in other courses. Such thinking encourages you to put anything down in hopes of partial credit. Instead, to be successful in this course requires you to demonstrate mastery. Instead of being "okay" at everything, you want to be "really good" at a few things.

Examples:

We provide example responses to the various types of questions based on a similar context. Consider the following problem set-up:

Brachydactyly Type D (commonly known as "clubbed thumb" or "stubby thumb") is a harmless genetic condition in which one or both thumbs are shorter with a wide nail. Research suggests approximately 2 percent of the population suffers from this condition (among them, Megan Fox and your instructor). Suppose that we are interested in determining if the proportion of current Rose-Hulman students who have this condition exceeds 2%. During their annual physicals, we examine the men on the football team, basketball team, and track team; for each student, we record whether he has the condition. The data is available in the data set `example` is constructed below.

```
example = tibble(
  Student = seq(50),
  Status = rep(c("Has Condition", "Does not Have Condition"), times = c(2, 48)))
```

Consider the following **computation question**:

What fraction of the students observed have *the condition of interest?*

Now, consider the following responses:

1.
```
summarize_variable((Status == "Has Condition") ~ 1, data = example, percent)
```
    - The observed proportion is 0.04.
2. 0.04
3.
```
summarize_variable((Status == "Does not Have Condition") ~ 1, data = example, percent)
```
    - The observed proportion is 0.96.

For the above question, response (1) is the correct solution and is considered successful. It has the correct numerical solution, and it clearly justifies the solution with the appropriate code. It also highlights the answer from the code (which is especially useful when the code returns more than just the answer provided).

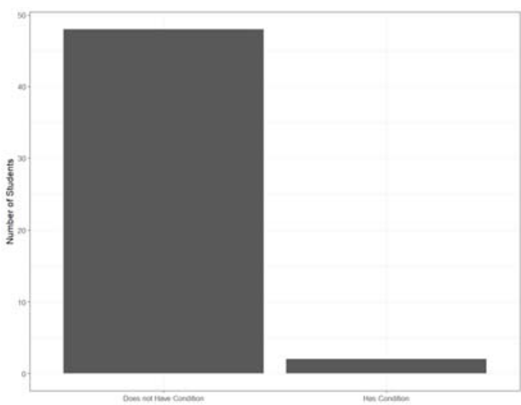
Response (2) has the correct numerical solution, but there is no justification for its computation (computer code/output). It is not successful.

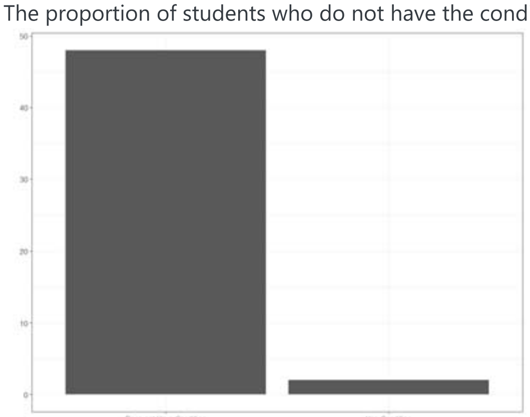
Response (3) has the correct idea but simply misread the problem. This does not fundamentally change the intent of this question (which is determined by the instructor) and therefore would in many cases still be considered a successful completion.

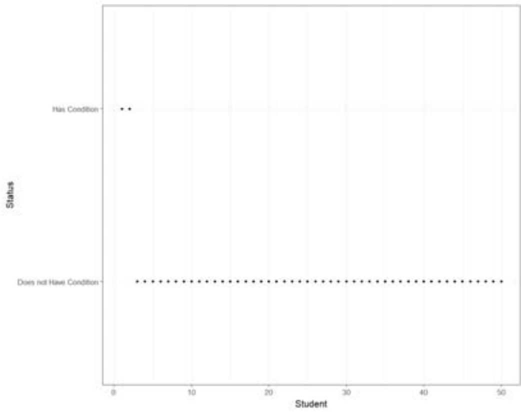
Consider the following **graphical summary**:

Provide a graphical summary of the raw data which would help address the question of interest and describe the graphic.

Conser the following graphics:

1. 

The proportion of students who do not have the condition is much larger than the proportion that does have the condtion.
2. 

3. 

This is a dotplot showing the number of students in each group.

For the above question graphic (1) would be successful. The graphic summarizes the distribution of the variable in the sample which is needed to answer the question. The axes are clear. And, a description that highlights the story communicated by the graphic is provided.

The second graphic, while similar to the first, does not provide a clear label on the y-axis.

The third graphic is not an appropriate summary given the type of data (categorical and not quantitative). Further, neither label is clear. Finally, the description is technical instead of telling the story communicated by the graphic.

Consider the following **definition/identification statement**:

Define the parameter of interest in this study.

1. The proportion of current Rose-Hulman students who have the condition.
2. The proportion.
3. The number of Rose-Hulman students who have the condition.
4. 0.04
5. Whether a Rose-Hulman student has the condition.
6. Whether the proportion of current Rose-Hulman students is greater than 0.02.

Response (1) is correct and would pass; it indicates the summarizing component (proportion), the variable (whether they have the condition), and the population (current Rose-Hulman students).

Response (2) leaves out components required to adequately define the parameter; it is not clear what we are taking the proportion of.

Response (3) is nearly correct, but the "number" refers to the statistic not the parameter.

Response (4) mistakes the sample statistic with the parameter.

Response (5) correctly states the variable of interest, but not the parameter.

Response (6) would not pass either; while it seems similar, it embeds the question fundamentally changing the hypothesis.

Consider the following **hypotheses** question:

State the null and alternative hypotheses which capture the above question of interest.

1. Let θ be the parameter defined above; then $H_0 : \theta \leq 0.02 \quad \text{vs.} \quad H_1 : \theta > 0.02$
2. H0: the proportion of current Rose-Hulman students who have the condition does not exceed 0.02. H1: the proportion of current Rose-Hulman students who have the condition exceeds 0.02.
3. $H_0 : \theta < 0.02 \quad \text{vs.} \quad H_1 : \theta \geq 0.02$
4. $H_0 : \theta > 0.02 \quad \text{vs.} \quad H_1 : \theta \leq 0.02$
5. H0: whether Rose-Hulman students have the condition is less than or equal to 0.02. H1: whether Rose-Hulman students have the condition is greater than 0.02.

Response (1) is correct and would pass; it references the previous answer and so defines the parameter. The hypotheses are correct and identify the question of interest.

Response (2) is also correct and would pass; while it does not use mathematical notation, the hypotheses contain all the necessary components.

Response (3) would not pass; the inequality is placed within the wrong hypothesis. This may seem subtle, but it is important for the mathematical justification of our analyses.

Response (4) would not pass; the hypotheses are switched for capturing the question of interest, fundamentally changing the question.

Response (5) would not pass; the hypotheses do not contain the parameter of interest (no proportion), violating a fundamental idea of the course.

Consider the following **model** question:

In addition to whether each student has the condition, the weight (in pounds) and height (in inches) was recorded for each student; write a model for the data generating process describing the weight of a student as a linear function of their height.

1. $(\texttt{Weight})_i = \beta_0 + \beta_1(\text{Height})_i + \varepsilon_i$
2. $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$
3. $(\text{Weight}) = \beta_0 + \beta_1(\text{Height}) + \varepsilon$

Response (1) is correct and would pass; it has the correct form of the model written in mathematical notation and includes all appropriate indices.

Response (2) would not pass; it does not identify the response variable or predictor preventing clear communication.

Response (3) would not pass; it clearly communicates the idea, but misses the technical inclusion of indices on the variables.

Consider the following **conclusion:**

Suppose we compute a p-value of 0.264 for the above hypotheses using the data provided. What conclusions can be drawn?

1. There is no evidence that the proportion of current Rose-Hulman students with the condition exceeds 0.02. The p-value of 0.264 is much higher than commonly accepted thresholds such as 0.05.
2. Fail to reject the null because 0.264 > 0.05.
3. There is evidence that the proportion of current Rose-Hulman students with the condition exceeds 0.02 because the p-value is large, and large p-values provide evidence.
4. The proportion of Rose-Hulman students with the condition does not exceed 0.02 (p-value = 0.264).

Response (1) is correct and would pass; it gives the conclusion in context (no jargon) and uses the p-value to justify the conclusion, including why the p-value gives the conclusion.

Response (2) is correct but is not placed in the context of the problem; this misses a major component of the specifications, and it would therefore not pass.

Response (3) misapplies the p-value.

Response (4) gives an inaccurate representation of the conclusion (cannot prove the null hypothesis); it also fails to explain how the p-value was used to reach the conclusion.

Consider the following request to assess the **conditions** of the analysis:

Assuming the data is presented in the order in which it was collected, is it reasonable to assume the data is stationary? Explain.

1. No, it is not reasonable. Looking at a plot of the response over time, there is a clear trend in that the first two respondents had the condition and no one else did after that. If stationarity was met, we would expect there to be no pattern in the plot of the response over time.
2. Yes, it is reasonable. Looking at the plot of the response over time, there is no clear trend in the graphic. This is consistent with what we would expect if the data generating process were stationary.
3. No, it is not reasonable; there was a trend in the plot.
4. Yes, it is reasonable. I can't imagine how the condition of one individual could be related to another person having the condition.
5. Looking at a plot of the response over time, there is a clear trend in that the first two respondents had the condition and no one else did after that. If stationarity was met, we would expect there to be no pattern in the plot of the response over time.

Responses (1) and (2) are both deserving of a pass. Notice that they come to different conclusions, but given that this is a very subjective interpretation of the graphic (which is not clear cut), either answer is appropriate. Both are consistent in their logic and give the answer, discuss the trends observed in the graphic and what they expected.

Response (3) would not pass. It does not describe what should be expected; therefore, the impact of the trend they observed is not clear.

Response (4) would not pass. It does not rely on the course content and an appropriate method for assessing the condition.

Response (5) would not pass. While it has two correct statements, it does not actually answer the question; the conclusion is not obvious.

Note: if this were an Analysis Task, you would also need to provide the graphic being referenced in the response.

Now, consider the following **justification question**:

Would you trust the conclusions of this study? Explain.

1. No, I would not trust the results. The study only examined male athletes. This is most likely not a representative sample of the population (which was all students) as it is entirely possible females are more or less likely to have the condition.
2. No, I would not because the p-value was high.
3. No, because this is not a random sample.
4. This is most likely not a representative sample of the population (which was all students) as it is entirely possible females are more or less likely to have the condition.

Response (1) would pass. It addresses the question posed; it then describes what in the problem is important for coming to their conclusion. Then, the third sentence describes why that is important.

Response (2) would not pass. It uses incorrect logic; high p-values do not mean that the study is not trustworthy.

Response (3) would not pass. While the statement is correct, the reason the observation is important is not clearly explained. A lack of random sampling is not always bad.

Response (4) has a correct discussion but does not actually answer the question posed; their conclusion is not clear. Therefore, it would not pass.

Now, consider the following **edit question**:

A coach for the men's athletic teams comes across the resulting p-value and states "we have evidence that no more than 2% of male athletes have clubbed thumb." This statement is incorrect; provide a corrected statement.

1. We do not have evidence that more than 2% of male athletes have clubbed thumb.
2. The data is consistent with no more than 2% of male athletes have clubbed thumb.
3. We do not have evidence that no more than 2% of male athletes have clubbed thumb.
4. We have evidence that more than 2% of male athletes have clubbed thumb.
5. In our sample 4% of male athletes had clubbed thumb.

Responses (1) and (2) would both pass. While phrased differently, both responses give accurate statements reflecting the goal of the problem.

Response (3) would not pass. While the statement is accurate, it is simply a negation of the current statement, not a truly corrected statement.

Response (4) would not pass. This statement is also inaccurate as it misapplies the p-value (since the p-value was large).

Response (5) would not pass. While a true statement, this statement does not try to reflect the intent of the original statement, which was to interpret the p-value.

Finally, consider the following **multiple-choice question:**

Suppose we compute a p-value of 0.264 for the above hypotheses using the data provided. Assuming the data is representative of the population, which of the following conclusions is appropriate?

- *A. There is a 26.4% chance that the proportion of current students that have clubbed thumb exceeds 0.02.*
- *B. There is a 26.4% chance that the proportion of current students that have clubbed thumb is no more than 0.02.*
- *C. Assuming the proportion of current students that have clubbed thumb exceeds 0.02, there is a 26.4% chance we would observe a statistic this extreme or moreso in a sample this size.*
- *D. Assuming the proportion of current students that have clubbed thumb is no more than 0.02, there is a 26.4% chance we would observe a statistic this extreme or moreso in a sample this size.*

Now consider the following responses:

1. D
2. A
3. B, C, D
4. B, D

Response (1) is correct and would pass.

Response (2) is incorrect.

Responses (3) and (4) include the correct answer, but also include additional arguments that are incorrect. Therefore, it will not pass.

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