AP® Statistics

Sample Student Responses and Scoring Commentary

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Free-Response Question 3

☑ **Scoring Guidelines**

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Question 3: Focus on Sampling and Experimental Design   4 points

General Scoring Notes

- Each part of the question (indicated by a letter) is initially scored by determining if it meets the criteria for essentially correct (E), partially correct (P), or incorrect (I). The response is then categorized based on the scores assigned to each letter part and awarded an integer score between 0 and 4 (see the table at the end of the question).

- The model solution represents an ideal response to each part of the question, and the scoring criteria identify the specific components of the model solution that are used to determine the score.

Model Solution	Scoring
(a) This is an observational study. The researchers had the car owners estimate their mileage. The car owners were not randomly assigned a car model, so no treatment was imposed.	**Essentially correct (E)** if the response satisfies the following three components: 1. Identifies an observational study 2. Provides a justification based on no treatment being imposed 3. Includes context **Partially correct (P)** if the response satisfies only two of the three components required for E. **Incorrect (I)** if the response does not meet the criteria for E or P.

Additional Notes:

- A response that states the study is an experiment receives a score of I for part (a).
- A response that states "No random assignment of treatment" may satisfy component 2.
- A response may satisfy component 3 with car models, drivers, cars, owners, or members. Mileage alone does not satisfy component 3.

Model Solution	Scoring
(b) Number the days in the experiment from 1 to 70. Using a random number generator, generate 35 unique integers from 1 to 70, inclusive. Assign the days with those 35 unique integers for James to drive the car with autopilot and assign the remaining 35 days for James to drive the car without autopilot. (Alternative solution) Using 70 equally sized slips of paper, label 35 "with autopilot" and 35 "without autopilot." Mix the slips of paper in a bag. Each day for the 70 days, select a slip of paper (without replacement) to determine the driving method for that day.	**Essentially correct (E)** if the response satisfies the following three components: 1. Creates appropriate labels for the units/treatments 2. Describes how to correctly implement the random process so that every possible random assignment is equally likely 3. The response indicates a random process that results in 35 days assigned to using autopilot and 35 days assigned to not using autopilot **Partially correct (P)** if the response satisfies only two of the three components required for E. **Incorrect (I)** if the response does not meet the criteria for E or P.

Additional Notes:

- For responses that use slips of paper (or marbles or equivalent) to represent treatments
  - To satisfy component 1 some slips must be labeled or assigned to represent autopilot and some labeled or assigned to represent no autopilot (e.g., blue marbles represent autopilot and yellow marbles represent no autopilot).
  - To satisfy component 2 the slips of paper must be mixed/shuffled, and the response must clearly link the treatment selected to a day (e.g., each day James selects a slip to determine the driving method).
  - To satisfy component 3 the response must indicate that there are 35 slips (or marbles of a specific color) for each treatment and the response must indicate that slips of paper (marbles) are selected without replacement.
- For responses that use slips of paper labeled from 1 to 70 (or an equivalent interval)
  - To satisfy component 1 the days must be labeled 1 to 70.
  - To satisfy component 2 the slips of paper must be mixed/shuffled, and the response must clearly link the day number selected to autopilot or no autopilot.
  - To satisfy component 3 the response must indicate that slips of paper are selected without replacement and that 35 days are assigned to each treatment.
- For responses that use a random number generator with days labeled from 1 to 70 (or an equivalent interval)
  - To satisfy component 1 the days must be labeled 1 to 70.
  - To satisfy component 2 the response indicates that the random number generator selects numbers 1 to 70 inclusive, and the response clearly links the day number selected to autopilot or no autopilot.
  - To satisfy component 3 the response must indicate that numbers are selected without repeats and that 35 days are assigned to each treatment.

- For responses that flip a coin for each day (or roll a die and note odd/even, generate a random number 1 or 2, or equivalent)
  - To satisfy component 1 each outcome must be linked to a treatment (e.g., heads equals autopilot, tails equals no autopilot).
  - To satisfy component 2 the response must clearly link the outcome of the coin flip to a day (e.g., each day James flips a coin to determine the driving method). Note: If the response includes a stopping rule (e.g., when 35 days are assigned one treatment, the remaining days are assigned the other treatment), component 2 is not satisfied because this plan increases the probability that the last days will have the same treatment, which does not meet the equally likely random assignment requirement.
  - To satisfy component 3 the response must indicate that 35 days are assigned to each treatment using a stopping rule. If there is no stopping rule, component 3 is not satisfied.
- If a response uses a random number generator or slips of paper with the numbers 1 to 70 and does not initially number the days from 1 to 70, component 1 may be satisfied if the response indicates a link between the number selected and the day (e.g., if 3 is selected, James uses autopilot on the third day).
- Responses that do not use any random process should be scored I. For example, "number the days from 1 to 70 and use autopilot on odd-numbered days."
- Responses that use blocking do not satisfy component 2 because all possible random assignments are not equally likely.
- If the response describes two ways to perform the random assignment, assign the score for the weaker assignment process.

Model Solution	Scoring
(c) In order to generalize his findings to all Model D cars in his club, he would need to randomly select Model D cars from the club. He would then need to carry out a similar study using the Model D cars that were randomly sampled from the club.	**Essentially correct (E)** if the response satisfies the following three components: 1. The response indicates that more cars must be sampled 2. The response indicates that random sampling is required for generalization 3. The response is in context, which would include sampling from the population of interest (Model D cars from his club) **Partially correct (P)** if the response satisfies only two of the three components required for E. **Incorrect (I)** if the response does not meet the criteria for E or P.

Additional Notes:

- Component 3 may be satisfied by using "members" of the club or "owners" in the club rather than cars.
- Any discussion of experimental design beyond the sample selection (such as conditions or two-sample design) should be ignored.

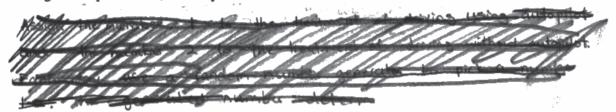| Scoring for Question 3	Score
Complete Response Three parts essentially correct	**4**
Substantial Response Two parts essentially correct and one part partially correct	**3**

Developing Response
 Two parts essentially correct and no part partially correct
     OR
 One part essentially correct and one or two parts partially correct
     OR
 Three parts partially correct
	2

Minimal Response One part essentially correct and no part partially correct *OR* No part essentially correct and two parts partially correct	**1**

Question 3

Begin your response to **QUESTION 3** on this page.

3. A car maker produces four different models of cars: A, B, C, and D. A group of researchers is investigating which model of car has the longest distance traveled per gallon of gas (mileage). Higher mileage is considered better than lower mileage. The researchers will conduct a study in which they contact several owners of each model of car and ask them to estimate their mileage.

(a) Is this an observational study or an experiment? Justify your answer in context.

Observational study. There are no treatments that are randomly being assigned to subjects. The researchers are only asking car owners of each model for an estimate of their mileage.

Model D has an autopilot feature, in which the car controls its own motion with human supervision. James owns a Model D car and will investigate whether using the autopilot feature results in higher mileage than not using the autopilot. James will drive his car on 70 different days to and from work, using the same route at the same time each day. James will record the mileage each day.

(b) James will use a completely randomized design to conduct his investigation. Describe an appropriate method James could use to randomly assign the two treatments, driving using the autopilot feature and driving without using the autopilot feature, to 35 days each.

~~Assign the numbers 1 to the days using autopilot and the numbers 2 to the kinds of driving without autopilot. assign to 2 and ... pick number ... get with number letter~~

Number each of the 70 days with a number 1-70, inclusive. Use a random number generator to pick 35 numbers between 1 and 70 without replacement. Each of the 35 numbers picked will correspond to a day. The 35 days selected will be assigned the treatment of driving using autopilot feature and the remaining days will be assigned the treatment of driving without autopilot feature.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Q5261/6

Question 3

Continue your response to **QUESTION 3** on this page.

(c) After the investigation was completed, James verified that the conditions for inference were met and conducted a hypothesis test. He discovered the mean mileage when using the autopilot feature was significantly higher than the mean mileage when not using the autopilot feature.

James is a member of a Model D club with thousands of members who all drive Model D cars. He will give a presentation at a Model D club members' meeting later this year and would like to state that the results of his hypothesis test apply to all Model D cars in his club. Another member of the club who is a statistician tells James his findings do not apply to all Model D cars in the club. What change would James need to make to his original study to be able to generalize to all Model D cars in the club?

James would need to replicate his study to a random sample of Model D owners in the club to be able to generalize the results to all Model D cars in the club.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

0200202

QS261/7

Question 3

Begin your response to **QUESTION 3** on this page.

3. A car maker produces four different models of cars: A, B, C, and D. A group of researchers is investigating which model of car has the longest distance traveled per gallon of gas (mileage). Higher mileage is considered better than lower mileage. The researchers will conduct a study in which they contact several owners of each model of car and ask them to estimate their mileage.

(a) Is this an observational study or an experiment? Justify your answer in context.

this is an observational study because they arent randomly assigning people to random models, they are surveying owners that already owned the car.

Model D has an autopilot feature, in which the car controls its own motion with human supervision. James owns a Model D car and will investigate whether using the autopilot feature results in higher mileage than not using the autopilot. James will drive his car on 70 different days to and from work, using the same route at the same time each day. James will record the mileage each day.

(b) James will use a completely randomized design to conduct his investigation. Describe an appropriate method James could use to randomly assign the two treatments, driving using the autopilot feature and driving without using the autopilot feature, to 35 days each.

James could flip a coin to decide which treatment to use, for example, if it lands on heads, he uses the auto pilot, and if its on tails, he doesn't use the autopilot, He does it once every-day.

Page 6   **GO ON TO THE NEXT PAGE.**

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Q5261/6

Question 3

Continue your response to **QUESTION 3** on this page.

(c) After the investigation was completed, James verified that the conditions for inference were met and conducted a hypothesis test. He discovered the mean mileage when using the autopilot feature was significantly higher than the mean mileage when not using the autopilot feature.

James is a member of a Model D club with thousands of members who all drive Model D cars. He will give a presentation at a Model D club members' meeting later this year and would like to state that the results of his hypothesis test apply to all Model D cars in his club. Another member of the club who is a statistician tells James his findings do not apply to all Model D cars in the club. What change would James need to make to his original study to be able to generalize to all Model D cars in the club?

James would have to ~~get~~ gather random model D members, and have them conduct the same experiment to generalize all of the Model D cars in the club.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

0156987

Q5261/7

Question 3

Begin your response to **QUESTION 3** on this page.

3. A car maker produces four different models of cars: A, B, C, and D. A group of researchers is investigating which model of car has the longest distance traveled per gallon of gas (mileage). Higher mileage is considered better than lower mileage. The researchers will conduct a study in which they contact several owners of each model of car and ask them to estimate their mileage.

(a) Is this an observational study or an experiment? Justify your answer in context.

This is an observational study, because there are no variables that are changed or altered. The researchers are just observing.

Model D has an autopilot feature, in which the car controls its own motion with human supervision. James owns a Model D car and will investigate whether using the autopilot feature results in higher mileage than not using the autopilot. James will drive his car on 70 different days to and from work, using the same route at the same time each day. James will record the mileage each day. $n = 70$

(b) James will use a completely randomized design to conduct his investigation. Describe an appropriate method James could use to randomly assign the two treatments, driving using the autopilot feature and driving without using the autopilot feature, to 35 days each.

James could use a random number generator without replacement, with numbers 1 through 70. The first 35 random numbers that come up will be days assigned to use autopilot. An example, the number 45 comes up, so on the 45th day of the study James will use autopilot. The last 35 numbers will be assigned as days James will drive his car.

Page 6   **GO ON TO THE NEXT PAGE.**

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Q5261/6

Question 3

Continue your response to **QUESTION 3** on this page.

(c) After the investigation was completed, James verified that the conditions for inference were met and conducted a hypothesis test. He discovered the <u>mean mileage when using the autopilot feature was significantly higher than the mean mileage when not using the autopilot feature.</u>

James is a member of a Model D club with thousands of members who all drive Model D cars. He will give a presentation at a Model D club members' meeting later this year and would like to state that the results of his hypothesis test apply to all Model D cars in his club. Another member of the club who is a statistician tells James his findings do not apply to all Model D cars in the club. What change would James need to make to his original study to be able to generalize to all Model D cars in the club?

James would need to use Model D cars from different Years to be able to generalize it to all Model D cars. Or he would have to use different drivers for different model D cars, to make sure his driving isn't affecting the results.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

0200548

Q6261/7

Question 3

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The primary goals of the question were to assess a student's ability to (1) identify an observational study with justification that no treatments were imposed; (2) describe a correct procedure for randomly assigning the use of the autopilot feature to the observational units in a completely randomized design; and (3) indicate the change to the original study that would allow the results to be generalized to all Model D cars in the club.

This question primarily assesses skills in skill category 1: Selecting Statistical Methods and skill category 4: Statistical Argumentation. Skills required for responding to this question include (1.B) Identify key and relevant information to answer a question or solve a problem, (1.C) Describe an appropriate method for gathering and representing data, (4.B) Interpret statistical calculations and findings to assign meaning or assess a claim, and (4.E) Justify a claim using a decision based on significance tests.

This question covers content from Unit 3: Collecting Data and Unit 7: Inference for Quantitative Data: Means of the course framework in the AP Statistics Course and Exam Description. Refer to topics 3.2, 3.3, 3.5, 3.7, and 7.5, and learning objectives DAT-2.A, DAT-2.C, DAT-3.F, VAR-3.B, VAR-3.C, and VAR-3.E.

Sample: 3A
Score: 4

The response earned the following: Part (a) – E; Part (b) – E; Part (c) – E.

In part (a) the response indicates an observational study, satisfying component 1. The response states that "there are no treatments that are randomly being assigned to subjects," satisfying component 2. The identification of "car owners" satisfies component 3. Part (a) was scored essentially correct (E).

In part (b) the response labels the days from $1 - 70,$ satisfying component 1. The response uses a random number generator to select numbers from $1 - 70$ and links the selected numbers to autopilot or no autopilot, satisfying component 2. The random process includes sampling without replacement, which results in 35 days assigned to each treatment, satisfying component 3. Part (b) was scored essentially correct (E).

In part (c) the response indicates that more cars must be sampled by referencing "owners" plural, satisfying component 1. The response indicates a random sample is required for generalization, satisfying component 2. The response satisfies component 3, identifying the population of interest with "Model D owners in the club." Part (c) was scored essentially correct (E).

Sample: 3B
Score: 3

The response earned the following: Part (a) – E; Part (b) – P; Part (c) – E.

In part (a) the response indicates an observational study, satisfying component 1. The response states that "they aren't randomly assigning people to random models," satisfying component 2. The identification of "models" satisfies component 3. Part (a) was scored essentially correct (E).

Question 3 (continued)

In part (b) the response links each outcome of a coin flip to "uses the autopilot" or "doesn't use the autopilot," satisfying component 1. The response correctly uses the result of a coin flip each day to assign a treatment, satisfying component 2. The random process does not ensure that 35 days are assigned to each treatment; therefore, component 3 is not satisfied. Part (b) was scored partially correct (P).

In part (c) the response indicates that more "members" must be sampled, satisfying component 1. The response indicates that members should be selected randomly, satisfying component 2. The response satisfies component 3 as the response identifies the population of interest with "Model D members." The mention of "members" alone would minimally satisfy component 3. Part (c) was scored essentially correct (E).

Sample: 3C
Score: 1

The response earned the following: Part (a) – I; Part (b) – E; Part (c) – I.

In part (a) the response indicates an observational study, satisfying component 1. The response does not satisfy component 2 by stating that no treatment is imposed. No context is included, so component 3 is not satisfied. Part (a) was scored incorrect (I).

In part (b) the response uses numbers from $1 - 70$ to indicate days by giving an example, satisfying component 1. The response uses a random number generator to select numbers from $1 - 70$ and links the selected numbers to the autopilot feature, with the remaining days assigned to no autopilot with "James will drive his car," satisfying component 2. The random process uses sampling without replacement and results in 35 days assigned to each treatment, satisfying component 3. Part (b) was scored essentially correct (E).

In part (c) the response indicates that multiple cars should be used, satisfying component 1. Component 2 is not satisfied, as the response does not indicate that the additional cars should be randomly selected. Component 3 is not satisfied, as there is no mention of cars in the club. Part (c) was scored incorrect (I).