2019

AP® CollegeBoard

AP® Statistics

Sample Student Responses and Scoring Commentary

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Question 2

Intent of Question

The primary goals of this question were to assess a student's ability to (1) identify components of an experiment; (2) determine if an experiment has a control group; and (3) describe how experimental units can be randomly assigned to treatments.

Solution

Part (a):

Treatments: Sprays with four different concentrations of the fungus (0 ml/L, 1.25 ml/L, 2.5 ml/L, and 3.75 ml/L)

Experimental units: 20 containers, each containing the same number of insects

Response variable: Number of insects that are still alive in each container one week after spraying

Part (b):

Yes. Because the 0 ml/L concentration contains no fungus, the containers that are sprayed with the 0 ml/L concentration form the control group.

Part (c):

Label each container with a unique integer from 1 to 20. Then use a random number generator to choose 15 integers from 1 to 20 without replacement. Use the first five of these numbers to identify the five containers that will receive the 0 ml/L treatment. Use the second five of these numbers to identify the five containers that will receive the 1.25 ml/L treatment. Use the third five of these numbers to identify the five containers that will receive the 2.5 ml/L treatment. The remaining five containers will receive the 3.75 ml/L treatment.

(Alternative solution) Using 20 equally sized slips of paper, label five slips with 0 ml/L, five slips with 1.25 ml/L, five slips with 2.5 ml/L, and five slips with 3.75 ml/L. Mix the slips of paper in a hat. For each container, select a slip of paper from the hat (without replacement) and spray that container with the treatment selected.

Question 2 (continued)

Scoring

Parts (a), (b), and (c) are each scored as essentially correct (E), partially correct (P), or incorrect (I).

Part (a) is scored as follows:

Essentially correct (E) if the response satisfies the following three components:

1. Identifies the 4 concentrations (or mixtures or sprays) as the treatments
2. Identifies the 20 containers as the experimental units
3. Identifies the number of insects that are still alive in each container as the response variable

Partially correct (P) if response satisfies only two of the three components.

Incorrect (I) if the response does not meet the criteria for E or P.

Notes:

- Listing the four treatments satisfies component 1 (including ml/L is not required). However, if the list does not include all four treatments, component 1 is not satisfied.
- To satisfy component 1, the response must refer to plural concentrations/mixtures/sprays (e.g., the mixtures, the levels of the concentration). Referring only to the explanatory variable (concentration) does not satisfy component 1.
- The following responses satisfy component 2: “the 20 containers”; “the containers”; “the 20 groups of insects”; or “the groups of insects in each container.” References to only “groups of insects” do not satisfy component 2 because it is unclear if these groups are formed by treatment or by container.
- To satisfy component 3, it must be clear that the response variable is being measured separately for each experimental unit. A response that says only “number of insects alive” does not satisfy component 3 because it could be referring to the total number of insects alive.
- To satisfy component 3, the response must be stated as a variable by using “number of” or equivalent. For example, “insects alive in each container” is not a variable and would not satisfy component 3.
- If the response states that the insects are the experimental units, then component 3 can still be satisfied by providing a binary response variable for each insect (e.g., whether the insect lived or died, survival status).

Question 2 (continued)

Part (b) is scored as follows:

Essentially correct (E) if the response indicates that there is a control group and justifies this claim by identifying the control group or by explaining that there is a treatment which contains no fungus.

Partially correct (P) if the response indicates that there is no control group because every container is sprayed with some mixture

OR

if the response states that there is a control group but implies that 0 ml/L is not a treatment (e.g., "the containers with 0 ml/L form a control group because they don't receive a treatment"; "yes, there is a group that got no treatment").

Incorrect (I) if the response does not meet the criteria for E or P.

Notes:

- The response does not need to explain the purpose of a control group.
- The response does not need to explicitly say "yes"—it can be implied by stating that there is a control group or saying "the control group is …."

Part (c) is scored as follows:

Essentially correct (E) if the response satisfies the following three components:

1. Creates appropriate labels for the units/treatments (e.g., label the containers from 1 through 20, label 20 slips of paper with five for each treatment)
2. Describes how to correctly implement the random assignment process
3. The random assignment process results in an equal number of experimental units assigned to each treatment

Partially correct (P) if response satisfies only two of the three components.

Incorrect (I) if the response does not meet the criteria for E or P.

Notes:

- If the response states that insects are the experimental units in part (a), the response in part (c) can be in terms of insects or containers. In either case, the same three components are used to determine the score.
- If the response states that the containers are the experimental units in part (a), but only describes how to assign insects to treatments in part (c), component 1 is not satisfied.
- For responses that use slips of paper:
  - If the number of slips of paper is not equal to the number of experimental units, then component 1 is not satisfied. The slips of paper do not need to be specifically identified as equally-sized.
  - If the slips of paper are not mixed/shuffled or the slips are not "selected at random," component 2 is not satisfied. Sampling without replacement is implied when using slips of paper, unless the response specifies sampling with replacement.

Question 2 (continued)

- For responses that use random number generators (or a 20-sided die):
    - If the initial assignment of numbers to units does not give each unit the same probability of being assigned to each treatment (e.g., units are represented by different numbers of integers), then component 1 is not satisfied.
    - If the response does not indicate that the numbers are selected without replacement or that different numbers must be used, the response does not satisfy component 2. The response does not need to specify the interval of numbers from which they are selecting (e.g., randomly generate a number from 1 to 20).
- For responses that use a table of random digits:
    - If the initial assignment of numbers to units does not give each unit the same probability of being assigned to each treatment, component 1 is not satisfied. For example, responses that use the labels 1 to 20 (not 01 to 20) do not satisfy component 1 because label 1 has a $\frac{1}{10}$ probability of being selected but label 20 has a $\frac{1}{100}$ probability of being selected.
    - If the response does not indicate that the numbers are selected without replacement or that different numbers must be used, the response does not satisfy component 2. The response does not need to specify the interval of numbers from which they are selecting or state that the numbers corresponding to unused labels will be skipped (e.g., skip numbers 00 and 21 to 99).
- For responses that use a 4-sided die (or random integers from 1 to 4):
    - If the die is rolled for each experimental unit, then component 3 is not satisfied because an equal number of units per treatment is not guaranteed.
    - If the die is rolled for each experimental unit until treatments are "full," then component 1 is not satisfied because this setup doesn't allow for all possible random assignments to be equally likely (unless the order of the units is randomized initially).
- If a response groups the experimental units before any random assignment (e.g., forms five groups of four containers or four groups of five containers), and then randomly assigns treatments to the groups or randomly assigns treatments within each group, component 1 is not satisfied. However, if a response forms groups in the context of a randomized block design with a reasonable blocking variable, component 1 can be satisfied.
- If a response describes two different random assignment processes in detail (e.g., how to randomly assign insects to containers and how to assign containers to treatments), both descriptions are scored according to the three components and the lower score is used.
- Responses that assign experimental units only to groups and not to treatments (e.g., randomly select five containers and put them in group 1) do not satisfy component 3.
- If the response randomly assigns insects to containers, the containers must be assigned to a treatment to satisfy component 3. In this case, the assignment of treatment to container does not need to be at random to satisfy component 3.

Question 2 (continued)

4 Complete Response

Three parts essentially correct

3 Substantial Response

Two parts essentially correct and one part partially correct

2 Developing Response

Two parts essentially correct and no parts partially correct

OR

One part essentially correct and one or two parts partially correct

OR

Three parts partially correct

1 Minimal Response

One part essentially correct

OR

No parts essentially correct and two parts partially correct

2A1 2A1

2. Researchers are investigating the effectiveness of using a fungus to control the spread of an insect that destroys trees. The researchers will create four different concentrations of fungus mixtures: 0 milliliters per liter (ml/L), 1.25 ml/L, 2.5 ml/L, and 3.75 ml/L. An equal number of the insects will be placed into 20 individual containers. The group of insects in each container will be sprayed with one of the four mixtures, and the researchers will record the number of insects that are still alive in each container one week after spraying.

(a) Identify the treatments, experimental units, and response variable of the experiment.

Treatments:

The 4 different mixtures with different concentrations of fungus
1.) 0 ml/L
2.) 1.25 ml/L
3.) 2.5 ml/L
4.) 3.75 ml/L

Experimental units:

The 20 containers with a certain number of insects

Response variable:

The number of insects still alive in the container one week after spraying

(b) Does the experiment have a control group? Explain your answer.

Yes, the experiment has a control group. One of the mixtures that is a possible treatment has 0 ml/L of fungus in it, or in other words, no fungus, so that mixture would allow for the comparison of having fungus versus the default mixture (which has no fungus)

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(c) Describe how the treatments can be randomly assigned to the experimental units so that each treatment has the same number of units.

You could number the containers from 01 to 20, with each container getting a unique number. Then, put those numbers onto slips of paper and put them in a hat.*Draw a slip out, and record the number without placing it back in the hat. Repeat this process ~~three~~ four(4) more times. Those containers that correspond to the recorded numbers are assigned to mixture 1(0 ml/L of fungus). Draw ~~four~~ five(5) more slips without replacing them. Those corresponding containers are assigned to mixture 2(1.25 ml/L of fungus). Repeat this process twice more and assign the corresponding containers to mixtures 3(2.5 ml/L fungus) and 4(3.75 ml/L fungus).

*shake the hat to mix up the slips

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2B1 2B1

2. Researchers are investigating the effectiveness of using a fungus to control the spread of an insect that destroys trees. The researchers will create four different concentrations of fungus mixtures: 0 milliliters per liter (ml/L), 1.25 ml/L, 2.5 ml/L, and 3.75 ml/L. An equal number of the insects will be placed into 20 individual containers. The group of insects in each container will be sprayed with one of the four mixtures, and the researchers will record the number of insects that are still alive in each container one week after spraying.

(a) Identify the treatments, experimental units, and response variable of the experiment.

Treatments:

The treatments are the 0 ml/L, 1.25 ml/L, 2.5 ml/L, and 3.75 ml/L fungus mixtures

Experimental units:

The experimental units are the groups of insects in each container

Response variable:

The response variable is the number of insects alive in each container one week after spraying.

(b) Does the experiment have a control group? Explain your answer.

Yes, the experiment has a control group
The control group are the containers that are sprayed with 0 ml/L fungus mixture concentration.

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(c) Describe how the treatments can be randomly assigned to the experimental units so that each treatment has the same number of units.

First, write out the number 1 on 5 sheets of paper. Write the number 2 on another 5, the number 3 on another 5, and the number 4 on 5 sheets. Place the total of 20 sheets of paper in a hat and for each container, take out a piece of paper. If you take out a sheet that has a "1" on it, it'll recieve the 0 ml/L concentration of fungus mixture. If it has a 2, it will be the 1.25 ml/L, a 3 will be the 2.5 ml/L, and a 4 will be the 3.75 ml/L. Do not place the sheets of paper back into the hat once it's been taken out.

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2C1 2C1

2. Researchers are investigating the effectiveness of using a fungus to control the spread of an insect that destroys trees. The researchers will create four different concentrations of fungus mixtures: 0 milliliters per liter (ml/L), 1.25 ml/L, 2.5 ml/L, and 3.75 ml/L. An equal number of the insects will be placed into 20 individual containers. The group of insects in each container will be sprayed with one of the four mixtures, and the researchers will record the number of insects that are still alive in each container one week after spraying.

(a) Identify the treatments, experimental units, and response variable of the experiment.

Treatments:

Varying concentration of fungus mixtures (0 ml/L, 1.25 ml/L, 2.5 ml/L, 3.75 ml/L)

Experimental units:

Insects sprayed with one of the four mixtures

Response variable:

The number of insects still alive in the container 1 week after spraying

(b) Does the experiment have a control group? Explain your answer.

Yes, the experiment has a control group. One of the groups receives a fungus mixture concentration of 0 ml/L, it goes through the experiment yet does not receive a treatment and the # of insects alive from this control group will work as a base for comparison.

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(c) Describe how the treatments can be randomly assigned to the experimental units so that each treatment has the same number of units.

Each of the 20 containers are numbered from 1 to 20. Using a random number generator, generate 5 numbers within this range (1-20), make sure there are no repetition in numbers. These first five numbers correspond to the containers being assaigned to ~~[illegible]~~ the first fungus mixture, 0 ml/L. ~~[illegible]~~ Generate another set of five numbers, remember you can't repeat the number from the last set of five because they have already been assigned to the first mixture. ~~These~~ This set of five numbers will correspond to the containers being assaigned to the second mixture, 1.25 ml/L. Repeat this process for the 2.5ml/L mixture and 3.75ml/L mixture. ~~[illegible]~~ All 4 mixtures should have 5 containers, each

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Question 2

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

Overview

The primary goals of this question were to assess a student's ability to (1) identify components of an experiment; (2) determine if an experiment has a control group; and (3) describe how experimental units can be randomly assigned to treatments.

This question primarily assesses skills in skill category 1: Selecting Statistical Methods. Skills required for responding to this question include (1.B) Identify key and relevant information to answer a question or solve a problem and (1.C) Describe an appropriate method for gathering and representing data.

This question covers content from Unit 3: Collecting Data of the course framework in the AP Statistics Course and Exam Description. Refer to topic 3.5 and learning objectives VAR-3.A, VAR-3.B, and VAR-3.C.

Sample: 2A
Score: 4

In part (a) the response identifies the treatments in two ways ("The 4 different mixtures," "0 ml/L, 1.25 ml/L"), which satisfies component 1. The response also identifies the experimental units ("The 20 containers"), which satisfies component 2. Finally, the response identifies the response variable ("The number of insects still alive in the container"), which satisfies component 3. Because the response includes all three components, part (a) was scored as essentially correct.

In part (b) the response answers "Yes" and explains that there is a treatment which contains no fungus ("One of the mixtures … has 0 ml/L of fungus in it, or in other words, no fungus"). This response also goes beyond the question asked and describes the purpose of a control group. This description, while correct, isn't required. Part (b) was scored as essentially correct.

In part (c) the response labels the containers and slips of paper from 01–20, which satisfies component 1. The response also clearly explains how to implement the random assignment process using the slips of paper, including mixing the slips, which satisfies component 2. Finally, the random assignment process described guarantees that there will be five containers per treatment, which satisfies component 3. Because the response includes all three components, part (c) was scored as essentially correct.

Because three parts were scored as essentially correct, the response earned a score of 4.

Sample: 2B
Score: 3

In part (a) the response identifies the treatments by listing them ("0 ml/L, 1.25 ml/L"), which satisfies component 1. The response also identifies the experimental units ("the groups of insects in each container."), which satisfies component 2. Finally, the response identifies the response variable ("number of insects alive in each container"), which satisfies component 3. Because the response includes all three components, part (a) was scored as essentially correct.

In part (b), the response answers "Yes" and identifies the control group ("The control group are the containers that are sprayed with 0 ml/L fungus mixture concentration"). Part (b) was scored as essentially correct.

In part (c) the response labels 20 slips of paper, five with the number 1, five with the number 2 and so on, which satisfies component 1. The response explains how to implement the random assignment process using the slips of paper, but doesn't specify that the slips of paper must be mixed in the hat. Therefore, component 2 is not satisfied. Finally, the random assignment process described guarantees that there will be five containers per treatment, which satisfies component 3. Because the response includes two of the three components, part (c) was scored as partially correct.

Because two parts were scored as essentially correct, and one part was scored as partially correct, the response earned a score of 3.

Sample: 2C
Score: 2

In part (a) the response identifies the treatments in two ways ("Varying concentrations of fungus mixtures," "0 ml/L, 1.25 ml/L,"), which satisfies component 1. The response incorrectly identifies the insects as the experimental units, rather than the containers, so component 2 is not satisfied. Finally, the response identifies the response variable ("The number of insects still alive in the container"), satisfying component 3. Because the response satisfies two of the three components, part (a) was scored as partially correct.

In part (b) the response answers "Yes" and explains that there is a treatment which contains no fungus ("One of the groups receives a fungus mixture concentration of 0 ml/L"). However, the response also makes an incorrect statement saying that the control group "does not receive a treatment." This contradicts the response in part (a), which lists 0 ml/L as a treatment. Part (b) was scored as partially correct.

In part (c) the response labels the containers from 1 to 20, which satisfies component 1. The response also clearly explains how to implement the random assignment process using a random number generator, remembering to state that there should be "no repetition in numbers," which satisfies component 2. Finally, the random assignment process described guarantees that there will be five containers per treatment, which satisfies component 3. Because the response includes all three components, part (c) was scored as essentially correct.

Because one part was scored as essentially correct, and two parts were scored as partially correct, the response earned a score of 2.