2022

AP CollegeBoard

AP® Statistics

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 5

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 5: Multi-Focus — 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)	The sample median reduction in blood pressure for those eating dark chocolate, 7 mmHg, is greater than the sample median reduction in blood pressure for those eating white chocolate, about 0 mmHg.	**Essentially correct (E)** if the response satisfies the following three components: 1. The medians are correctly determined with the median for dark chocolate equal to 7 mmHg and the median for white chocolate between −2 mmHg and 2 mmHg, inclusive 2. The computed medians are compared correctly 3. The context of the response variable (reduction in blood pressure) and the treatment groups (dark chocolate and white chocolate) is included **Partially correct (P)** if the response satisfies two of the three components and, if stated, the reported values of the medians are reasonable *OR* if the response satisfies one of components 2 or 3 and the reported values of the medians are reasonable. **Incorrect (I)** if the response does not meet the criteria for E or P.

Additional Notes:

- To be scored as reasonable, the reported value of the median for the dark chocolate group must be between 5 mmHg and 8 mmHg, inclusive, and the reported value for the median of the white chocolate group must be between −2 mmHg and 3 mmHg, inclusive.

	Model Solution	Scoring
(b)	The researcher's conclusion may not necessarily be true because looking at the difference in sample means alone does not consider the variability in the sampling distribution of the differences in sample means. Another random assignment of subjects to dark and white chocolate may result in a sample mean reduction in blood pressure for subjects assigned to dark chocolate that is smaller than the mean reduction for subjects assigned to white chocolate. The variability in the sampling distribution of potential differences in sample means must be considered in making a conclusion about convincing statistical evidence. Further, an inference procedure can assess the likelihood that the observed difference in sample means occurred by random chance if the population means are equal.	**Essentially correct (E)** if the response satisfies at least two of the following three components: 1. Indicates that the researchers failed to consider the variability in the sampling distribution of differences in sample means (or that this should be considered) OR states that a different random assignment could produce different sample means 2. Includes an explanation that a difference of 5.66 mmHg could have occurred by random chance, even if the population means are equal 3. Indicates that an inference procedure is needed **Partially correct (P)** if the response satisfies only one of the three components. **Incorrect (I)** if the response does not meet the criteria for E or P.

Additional Notes:

- A response may be scored E if it states that no conclusion can be made about the relationship between the population mean blood pressure reduction for those who consume dark chocolate and those who consume white chocolate because the sample was drawn only from the subpopulation of *healthy* adults.

Model Solution	Scoring
(c) The observed value of the sample statistic $\bar{x}_{dark} - \bar{x}_{white}$ is 5.66 mmHg. The graph of simulation results reveals that a difference of 5.66 mmHg or larger occurred in only 3 of the 120 trials. Thus, the p-value is approximately equal to $\frac{3}{120} = 0.025$. Thus, assuming that there is no difference in mean blood pressure reduction, there is an approximate probability of 0.025 of getting a difference of 5.66 mmHg or larger by chance alone. Because this approximate p-value is less than 5 percent, there is convincing evidence that adding dark chocolate to the diet will result in a greater mean reduction in blood pressure than adding white chocolate to the diet for people similar to those who participated in the study.	**Essentially correct (E)** if the response satisfies the following four components: 1. Calculates the correct p-value of 0.025 2. Provides supporting work from the simulation for the calculation of the p-value 3. Provides a correct conclusion in the context of whether there is convincing evidence that adding dark chocolate to the diet will result in greater average reduction in blood pressure than adding white chocolate to the diet 4. Justifies the conclusion by directly comparing the calculated p-value to 0.05 **Partially correct (P)** if the response satisfies only two or three of the four components *OR* if the conclusion (component 3) is correct but is not in context and at least one additional component is satisfied *OR* if the conclusion (component 3) is in context and correct, but the justification is based on an analysis of the data shown in the dotplots (e.g., a two-sample t-confidence interval, a two-sample t-test, an appropriate nonparametric test, or an "exact" randomization test). **Incorrect (I)** if the response does not meet the criteria for E or P.

Additional Notes:

- Component 2 is satisfied by simply noting that only three of the simulated trials resulted in a difference of at least 5.66 mmHg, the observed difference.
- A response that incorrectly evaluates the p-value may still satisfy components 3 and 4 if the response is consistent with the use of the incorrect p-value.
- The hypotheses are not required because they are given in the stem.

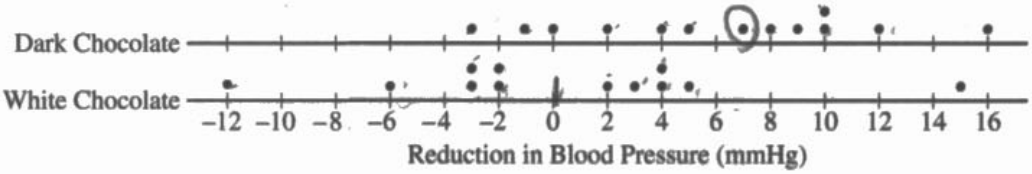
Scoring for Question 5	Score
Complete Response Three parts essentially correct	**4**
Substantial Response Two parts essentially correct and one part partially correct	**3**
Developing Response Two parts essentially correct and no part partially correct *OR* One part essentially correct and one or two 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 5

Begin your response to **QUESTION 5** on this page.

5. Studies have shown that foods rich in compounds known as flavonoids help lower blood pressure. Researchers conducted a study to investigate whether there was a greater reduction in blood pressure for people who consumed dark chocolate, which contains flavonoids, than people who consumed white chocolate, which does not contain flavonoids. Twenty-five healthy adults agreed to participate in the study and add 3.5 ounces of chocolate to their daily diets. Of the 25 participants, 13 were randomly assigned to the dark chocolate group and the rest were assigned to the white chocolate group. All participants had their blood pressure recorded, in millimeters of mercury (mmHg), before adding chocolate to their daily diets and again 30 days after adding chocolate to their daily diets.

The reduction in blood pressure (before minus after) for each of the participants in the two groups is shown in the dotplots below.



(a) Determine and compare the medians of the reduction in blood pressure for the two groups.

The median reduction in blood pressure for eating dark chocolate is 7 mm Hg higher than white, The mean reduction from white chocolate is 0 mm Hg while dark chocolate lowers it by 7 mm Hg.

The researchers found the mean reduction in blood pressure for those who consumed dark chocolate is $\bar{x}_{dark} = 6.08$ mmHg and the mean reduction in blood pressure for those who consumed white chocolate is $\bar{x}_{white} = 0.42$ mmHg.

(b) One researcher indicated that because the difference in sample means of 5.66 mmHg is greater than 0 there is convincing statistical evidence to conclude that the population mean blood pressure reduction for those who consume dark chocolate is greater than for those who consume white chocolate. Why might the researcher's conclusion, based only on the difference in sample means of 5.66 mmHg, not necessarily be true?

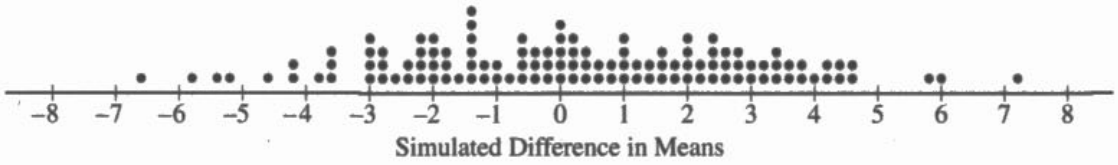
This conclusion does not account for sampling variability, this means this particular result can be because of chance that dark chocolate lowered blood pressure more than white chocolate rather than a real statistically significant result,

GO ON TO THE NEXT PAGE.

Question 5

Continue your response to **QUESTION 5** on this page.

A simulation was conducted to investigate whether there is a greater reduction of blood pressure for those who consume dark chocolate than for those who consume white chocolate. The simulation was conducted under the assumption that no difference exists. The results of 120 trials of the simulation are shown in the following dotplot.



(c) Use the results of the simulation to determine whether the results from the 25 participants in the study provide convincing statistical evidence, at a 5 percent level of significance, that adding dark chocolate to a daily diet will result in a greater reduction in blood pressure, on average, than adding white chocolate to a daily diet. Justify your answer.

The results from the 25 participant study is statistically significant.

using the simulated distribution above, only $\frac{3}{120}$ trials had 5.66 mmHg or greater differences in blood pressure,

This means p-value = $\frac{3}{120} = .025 < \alpha = .05$,

∴ we reject the null hypothesis that there is no difference in blood pressure reduction because p-value $= .025 < \alpha = .05$, to conclude dark chocolate in a daily diet will result in greater blood pressure reduction than white chocolate,

GO ON TO THE NEXT PAGE.

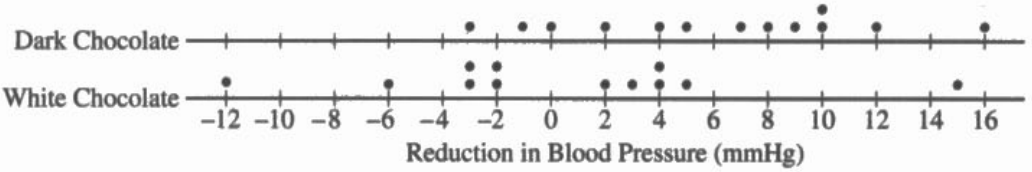
Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 5

Begin your response to **QUESTION 5** on this page.

5. Studies have shown that foods rich in compounds known as flavonoids help lower blood pressure. Researchers conducted a study to investigate whether there was a greater reduction in blood pressure for people who consumed dark chocolate, which contains flavonoids, than people who consumed white chocolate, which does not contain flavonoids. Twenty-five healthy adults agreed to participate in the study and add 3.5 ounces of chocolate to their daily diets. Of the 25 participants, 13 were randomly assigned to the dark chocolate group and the rest were assigned to the white chocolate group. All participants had their blood pressure recorded, in millimeters of mercury (mmHg), before adding chocolate to their daily diets and again 30 days after adding chocolate to their daily diets.

The reduction in blood pressure (before minus after) for each of the participants in the two groups is shown in the dotplots below.



(a) Determine and compare the medians of the reduction in blood pressure for the two groups.

The median blood pressure reduction is 7 for the dark chocolate group and 0 for the white chocolate group. The dark chocolate group has a higher median blood pressure reduction.

The researchers found the mean reduction in blood pressure for those who consumed dark chocolate is $\bar{x}_{dark} = 6.08$ mmHg and the mean reduction in blood pressure for those who consumed white chocolate is $\bar{x}_{white} = 0.42$ mmHg.

(b) One researcher indicated that because the difference in sample means of 5.66 mmHg is greater than 0 there is convincing statistical evidence to conclude that the population mean blood pressure reduction for those who consume dark chocolate is greater than for those who consume white chocolate. Why might the researcher's conclusion, based only on the difference in sample means of 5.66 mmHg, not necessarily be true?

You cannot conclude statistical significance based on sample means alone. An appropriate hypothesis test must be conducted to decide whether or not it is likely the difference in sample means was caused by random chance.

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.

Question 5

Continue your response to **QUESTION 5** on this page.

A simulation was conducted to investigate whether there is a greater reduction of blood pressure for those who consume dark chocolate than for those who consume white chocolate. The simulation was conducted under the assumption that no difference exists. The results of 120 trials of the simulation are shown in the following dotplot.

(c) Use the results of the simulation to determine whether the results from the 25 participants in the study provide convincing statistical evidence, at a 5 percent level of significance, that adding dark chocolate to a daily diet will result in a greater reduction in blood pressure, on average, than adding white chocolate to a daily diet. Justify your answer.

μ_1 = the true mean reduction in blood pressure for the dark chocolate group

μ_2 = the true mean reduction in blood pressure for the white chocolate group

H_0: $\mu_1 = \mu_2$ H_a: $\mu_1 > \mu_2$

Random: Treatments randomly assigned Independent - $N \geq 10(25)$ More than 250 healthy adults

Normal - Dotplot for the simulation has no heavy skew or outliers can assume approx normal.

2-Sample t-test

$t = 2.387$ $P = .013$ $df = 21.92$ $\alpha = .05$

Since the p-value of .013 is less than $\alpha = .05$, reject H_0. There is convincing evidence at the .05 significance level that adding dark chocolate to a daily diet results in a greater mean reduction in blood pressure than adding white chocolate.

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.

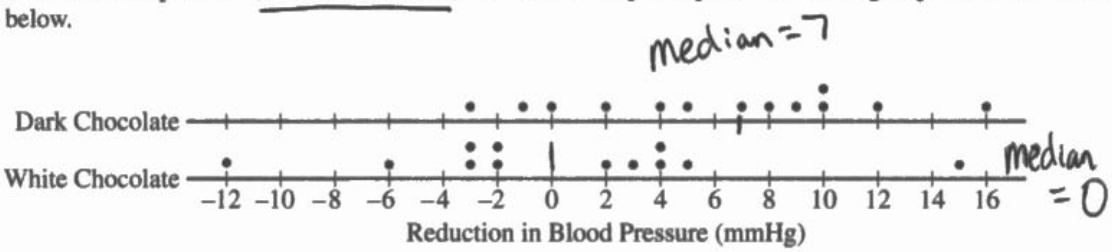
Question 5

Begin your response to **QUESTION 5** on this page.

5. Studies have shown that foods rich in compounds known as flavonoids help lower blood pressure. Researchers conducted a study to investigate whether there was a greater reduction in blood pressure for people who consumed dark chocolate, which contains flavonoids, than people who consumed white chocolate, which does not contain flavonoids. Twenty-five healthy adults agreed to participate in the study and add 3.5 ounces of chocolate to their daily diets. Of the 25 participants, 13 were randomly assigned to the dark chocolate group and the rest were assigned to the white chocolate group. All participants had their blood pressure recorded, in millimeters of mercury (mmHg), before adding chocolate to their daily diets and again 30 days after adding chocolate to their daily diets.

n=25

The reduction in blood pressure (before minus after) for each of the participants in the two groups is shown in the dotplots below.



(a) Determine and compare the medians of the reduction in blood pressure for the two groups.

The median for the Dark Chocolate "reduction" group blood pressure is 7 whereas the median for the White Chocolate group reduction in blood pressure is 0.

The researchers found the mean reduction in blood pressure for those who consumed dark chocolate is $\bar{x}_{dark} = 6.08$ mmHg and the mean reduction in blood pressure for those who consumed white chocolate is $\bar{x}_{white} = 0.42$ mmHg.

(b) One researcher indicated that because the difference in sample means of 5.66 mmHg is greater than 0 there is convincing statistical evidence to conclude that the population mean blood pressure reduction for those who consume dark chocolate is greater than for those who consume white chocolate. Why might the researcher's conclusion, based only on the difference in sample means of 5.66 mmHg, not necessarily be true?

The researcher is forming a conclusion based on 1 sample with no p-value. Without the proper significance test, there is no way to make a definite claim that the pop mean BP reduction for dark choc consumers is greater than that of white choc consumers.

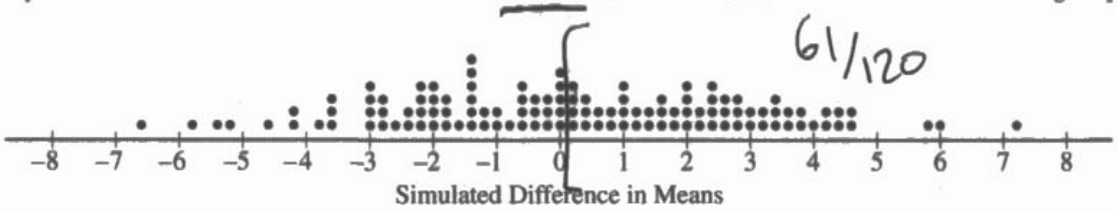
GO ON TO THE NEXT PAGE.

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

Question 5

Continue your response to **QUESTION 5** on this page.

A simulation was conducted to investigate whether there is a greater reduction of blood pressure for those who consume dark chocolate than for those who consume white chocolate. The simulation was conducted under the assumption that no difference exists. The results of 120 trials of the simulation are shown in the following dotplot.



(c) Use the results of the simulation to determine whether the results from the 25 participants in the study provide convincing statistical evidence, at a 5 percent level of significance, that adding dark chocolate to a daily diet will result in a greater reduction in blood pressure, on average, than adding white chocolate to a daily diet. Justify your answer.

Hypothesis: $H_0: \mu_D = \mu_W$

$H_a: \mu_D > \mu_W$

μ_D = true mean reduction in Blood Pressure for dark chocolate consumers

μ_W = true mean reduction in Blood Pressure for white chocolate consumers

p-value = $61/120 = .5083$

Fail to reject H_0 since the p-value = .5083 > .05. There is not enough convincing evidence to say that adding dark chocolate to a daily diet will result in a greater reduction in blood pressure, on average, than adding white chocolate to a daily diet.

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.

Question 5

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) compute and compare sample medians for data presented in two dotplots; (2) explain why a conclusion based only on the difference between two sample means may not necessarily be true; and (3) use results of a simulation, presented in a dotplot, to justify a conclusion about whether a study provides convincing statistical evidence that one treatment is better than another treatment.

This question primarily assesses skills in skill category 1: Selecting Statistical Methods, skill category 2: Data Analysis, and skill category 4: Statistical Argumentation. Skills required for responding to this question include (1.E) Identify an appropriate inference method for significance tests, (2.A) Describe data presented numerically or graphically, and (4.B) Interpret statistical calculations and findings to assign meaning or assess a claim.

This question covers content from Unit 1: Exploring One-Variable Data and Unit 7: Inference for Quantitative Data: Means of the course framework in the AP Statistics Course and Exam Description. Refer to topics 1.6, 7.8, and 7.9, and learning objectives UNC-1.H, VAR-7.F, and DAT-3.H.

Sample: 5A
Score: 4

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

In part (a) the first sentence correctly compares the medians for both samples, including context, satisfying components 2 and 3. The second sentence correctly states the medians for both groups, satisfying component 1. Part (a) was scored essentially correct (E).

In part (b) the response indicates that "[t]his conclusion does not account for sampling variability," satisfying component 1. The response also indicates that "this particular result can be because of chance," satisfying component 2. The response does not state the need for an inference procedure; thus, component 3 is not satisfied. Two of the three components are satisfied. Part (b) was scored essentially correct (E).

In part (c) the response calculates the correct *p*-value with supporting work, satisfying components 1 and 2. The response states that the *p*-value is less than α and provides a correct conclusion in context, satisfying components 3 and 4. Part (c) was scored essentially correct (E).

Sample: 5B
Score: 3

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

In part (a) the response correctly determines and compares the medians for both samples, including context. Part (a) was scored essentially correct (E).

In part (b) the response indicates that "[a]n appropriate hypothesis test must be conducted," satisfying component 3. The response also discusses whether "the difference in sample means was caused by random chance," satisfying component 2. The response does not indicate that the researchers should consider the variability of the sampling distribution; thus, component 1 is not satisfied. Two of the three components are satisfied. Part (b) was scored essentially correct (E).

Question 5 (continued)

In part (c) the response does not use the simulation to calculate the correct *p*-value; therefore, components 1 and 2 are not satisfied. The response provides a correct conclusion in context based on an analysis of the data, not the results of the simulation. Part (c) was scored partially correct (P).

Sample: 5C
Score: 2

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

In part (a) the response correctly determines the medians for both samples, including context; however, the response lacks a direct comparison of the medians. Part (a) was scored partially correct (P).

In part (b) the response indicates that an inference procedure is needed, satisfying component 3. The response does not indicate that the researchers should consider the variability of the sampling distribution, nor does it indicate that the difference could have occurred by random chance; thus, neither component 1 nor component 2 are satisfied. One of the three components is satisfied. Part (b) was scored partially correct (P).

In part (c) the response does not calculate the correct *p*-value, so component 1 is not satisfied. However, the response provides supporting work from the simulation, satisfying component 2. The response provides a conclusion consistent with their incorrect *p*-value, with justification, satisfying components 3 and 4. Part (c) was scored partially correct (P).