AP® STATISTICS
2006 SCORING GUIDELINES (Form B)

Question 5

Intent of Question

The primary goals of this question are to assess a student's ability to: (1) identify the response variable, treatments, and experimental units in a study; (2) critique the use of randomization and replication; (3) recognize and explain why a particular variable is a confounding variable.

Solution

Part (a):

The response variable was the amount of draft. The two treatments were the standard hitch and the new hitch. The experimental units were the two large plots of land.

Part (b):

Yes, the two hitches (treatments) were randomly assigned to the two plots (experimental units).

Part (c):

No, each treatment (type of hitch) was applied to only one experimental unit (plot of land). Replication is used to repeat the treatments on different experimental units so general patterns can be observed. There is no replication in this study.

Part (d):

Although 25 measurements were taken at different locations in the two plots, each hitch was used in one plot (experimental unit) only. Thus, if a difference in the draft is observed we will not know whether the difference is due to the hitch or the plot. In statistical language, the treatments (hitches) are confounded with the plots.

Scoring

Parts (a), (b), (c), and (d) are scored as essentially correct (E), partially correct (P), or incorrect (I). Each essentially correct response is worth 1 point; each partially correct answer is worth ½ point.

Part (a) is essentially correct (E) if the response variable, treatments, and experimental units are correctly identified.

Part (a) is partially correct (P) if two of the three components of the experiment are correctly identified.

Part (a) is incorrect (I) if one or less of the three components of the experiment is correctly identified.

Note:

Responses to parts (b), (c) and (d) must be considered with respect to the experimental units identified in part (a).

Question 5 (continued)

Part (b) is essentially correct (E) if the student correctly discusses the use of randomization in this experiment with respect to assignment of the two hitches for use in the two plots OR with respect to the experimental units identified in part (a).

Part (b) is partially correct (P) if the student recognizes the use of randomization in the experiment but provides an incomplete or unclear discussion.

Part (b) is incorrect (I) if the student

Recognizes that randomization was used properly but does not provide a justification. That is, a naked answer of "YES" is scored as incorrect.

OR

Provides a discussion that does not address the issue of randomization, e.g., the student indicates that the plots should be more alike.

Part (c) is essentially correct (E) if the student recognizes that replication was not used properly and provides a correct justification.

Part (c) is partially correct (P) if the student recognizes that replication was not used properly but provides an incomplete justification that reveals some understanding of replication.

Part (c) is incorrect (I) if the student

Recognizes that replication was not used properly but does not provide a justification.

OR

Fails to recognize that replication was not properly used, e.g., incorrectly argues that the 25 measurements taken on each experimental unit (plot) provide proper replication.

Part (d) is essentially correct (E) if the student provides a valid explanation of confounding in this experiment.

Part (d) is partially correct (P) if the student provides an incomplete explanation that indicates an understanding of confounding in this experiment. For example, the student indicates that differences in plot conditions can affect draft but fails to link this to the inability to distinguish between plots differences and hitch effects.

Part (d) is incorrect (I) if the student

Provides a textbook definition of confounding with no attempt to describe the confounding variable in this experiment.

OR

Fails to address the issue of confounding.

Alternative solutions for part (d):

Each treatment was used in only one plot. Therefore, any differences caused by the differences in plots (e.g., soil hardness, moisture level, etc.) cannot be separated from differences in the two treatments.

Because only one plot of land is assigned to each hitch, if no difference is found it could be due to a superior hitch in a poor field (highly compacted) being compared with an inferior hitch in a good field. The effect of the hitch is masked by the differences in the plot

Question 5 (continued)

4 **Complete Response**

3 **Substantial Response**

2 **Developing Response**

1 **Minimal Response**

If a response is between two scores (for example, 2½ points), use a holistic approach to determine whether to score up or down depending on the strength of the response and communication.

5. When a tractor pulls a plow through an agricultural field, the energy needed to pull that plow is called the draft. The draft is affected by environmental conditions such as soil type, terrain, and moisture.

A study was conducted to determine whether a newly developed hitch would be able to reduce draft compared to the standard hitch. (A hitch is used to connect the plow to the tractor.) Two large plots of land were used in this study. It was randomly determined which plot was to be plowed using the standard hitch. As the tractor plowed that plot, a measurement device on the tractor automatically recorded the draft at 25 randomly selected points in the plot.

After the plot was plowed, the hitch was changed from the standard one to the new one, a process that takes a substantial amount of time. Then the second plot was plowed using the new hitch. Twenty-five measurements of draft were also recorded at randomly selected points in this plot.

(a) What was the response variable in this study?

The response variable in this study was the draft.

Identify the treatments.

The two treatments were the two types of hitches: the standard hitch and the new hitch.

What were the experimental units?

The experimental units were the two large plots of land.

* clear indication of the effect of the newly developed hitch on draft reduction.

(b) Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was randomization used properly in this study? Justify your answer.

Randomization was used properly in this study because the experimental units (plots) were randomly assigned to the treatments (hitches), thus reducing chance variation resulting from differences in the environmental conditions between each plot, such as soil type, terrain, and moisture. Moreover, the locations at which draft measurements were taken were also randomized in order to further reduce variability arising from differences in those same environmental conditions within each plot. For instance, the north end of a particular plot could have more fertile soil and less rocky terrain than the south end of the same plot. Thus, the results of the study should provide a relatively *

(c) Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was replication used properly in this study? Justify your answer.

Replication was <u>not</u> used properly in this study because the newly developed hitch was not tested against the standard hitch more than once. Ideally, the hitches should have been tested on multiple plots of land (more than two), so that the results of the study would be reliable. However, because the hitches were only tested on one plot of land apiece, it is not reasonable to draw conclusions about the draft-reducing capability of the newly developed hitch from the study's results.

(d) Plot of land is a confounding variable in this experiment. Explain why.

Plot of land is a confounding variable because the variability inherent in each plot's environmental conditions, such as soil type, terrain, and moisture can potentially have a large influence on the measurements of the response variable - draft, thus making it unclear whether the difference in the type of hitch or differences in the plots' environmental features, affected the measured differences in draft.

5B1

5. When a tractor pulls a plow through an agricultural field, the energy needed to pull that plow is called the draft. The draft is affected by environmental conditions such as soil type, terrain, and moisture.

A study was conducted to determine whether a newly developed hitch would be able to reduce draft compared to the standard hitch. (A hitch is used to connect the plow to the tractor.) Two large plots of land were used in this study. It was randomly determined which plot was to be plowed using the standard hitch. As the tractor plowed that plot, a measurement device on the tractor automatically recorded the draft at 25 randomly selected points in the plot.

After the plot was plowed, the hitch was changed from the standard one to the new one, a process that takes a substantial amount of time. Then the second plot was plowed using the new hitch. Twenty-five measurements of draft were also recorded at randomly selected points in this plot.

(a) What was the response variable in this study?

draft

Identify the treatments.

Treatment 1: newly developed hitch

Treatment 2: standard hitch

What were the experimental units?

The experimental units are the randomly selected points in the plot.

(b) Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was randomization used properly in this study? Justify your answer.

Yes, randomization was used properly in this study. It was randomly decided which hitch would plow each plot, and the points where recording the draft would take place. The only aspect of the experiment that was not randomized was which plot, with which hitch would be plowed first. This could have affected the draft, because the tractor's conditions could be different

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5B2

(c) Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was replication used properly in this study? Justify your answer.

No, replication was not used properly in this study. In fact, no replication was involved. Replication is when an experiment is repeated. Replicating this experiment would mean plowing two completely different fields with the two different hitches.

(d) Plot of land is a confounding variable in this experiment. Explain why.

A confounding varible is when some external factor effects the results of the experiment. The plot of land is a confounding variable because the soil could be harder/more compact and make it more difficult for the plow (therefore increasing draft). Or, the moisture of the soil or bumpiness of terrain could effect the draft.

5. When a tractor pulls a plow through an agricultural field, the energy needed to pull that plow is called the draft. The draft is affected by environmental conditions such as soil type, terrain, and moisture.

A study was conducted to determine whether a newly developed hitch would be able to reduce draft compared to the standard hitch. (A hitch is used to connect the plow to the tractor.) Two large plots of land were used in this study. It was randomly determined which plot was to be plowed using the standard hitch. As the tractor plowed that plot, a measurement device on the tractor automatically recorded the draft at 25 randomly selected points in the plot.

After the plot was plowed, the hitch was changed from the standard one to the new one, a process that takes a substantial amount of time. Then the second plot was plowed using the new hitch. Twenty-five measurements of draft were also recorded at randomly selected points in this plot.

(a) What was the response variable in this study?

the draft measured by the device

Identify the treatments.

plowing with a new hitch and plowing with a standard hitch

What were the experimental units?

the two hitches

(b) Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was randomization used properly in this study? Justify your answer.

randomization was used properly in this study because it was randomly selected which plot would be plowed using the standard hitch.

(c) Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was replication used properly in this study? Justify your answer.

replication was not used properly in this study because the was no replication of the study, researchers should have had the study repeated under controlled conditions to verify results and redvce variability.

(d) Plot of land is a confounding variable in this experiment. Explain why.

Because changing the hitch can take a substantial amount of time between plowing, the plot of land could theoretically change. For example, the level of moisture in the soil, which affects draft, could change over the period of the day and hinder the results of the study.

AP® STATISTICS
2006 SCORING COMMENTARY (Form B)

Question 5

Sample: 5A
Score: 4

This essay correctly identifies the basic parts of the experiment. The response variable is the draft, or energy required to pull the plow. The treatments are the two types of hitches, and the experimental units are the two large plots of land. Part (b) clearly recognizes that the two large plots of land (experimental units) were randomly assigned to be plowed with one of the two hitches (treatments). The essay goes on to discuss the random selection of 25 points in each large plot at which measurements were made. This is random sampling, which should not be confused with randomization, the act of randomly assigning experimental units to treatments. Randomly selecting the points is a good thing to do, however, because it helps to avoid bias, and this discussion does not contradict the first sentence in which the appropriate use of randomization is recognized. A weakness in this response is that it indicates that randomization reduces variability. This is not correct. Since random assignment of experimental units to treatments converts potential sources of bias into random variation, randomization reduces bias but it does not reduce variability. Part (c) clearly recognizes that there is no replication in this study because each hitch was used to plow only one plot. Each hitch must be used in more than one plot to have replication. (The draft measurements taken at the 25 randomly selected points in each plot would be averaged to obtain a single average draft measurement for the plot, but taking several measurements on the same experimental unit is not true replication). Since each hitch is used on only one plot, and varying conditions across plots can affect the energy needed to pull the plow, any difference in draft due to the different hitches cannot be distinguished from the difference in the conditions in the two plots. The overall strength of responses and level of communication provided by this essay more than compensate for the weakness in the response to part (b), so this essay was scored as essentially correct.

Sample: 5B
Score: 3

This essay incorrectly identifies the experimental units as the randomly selected points within the plots but goes on to correctly discuss randomization in part (b) in the context of randomly assigning the large plots to the hitches. Part (b) includes another good suggestion that the order in which the hitches were used should also have been randomized. Part (c) correctly recognizes the lack of replication in the study. Part (d) is only partially complete in the sense that it recalls the information given in the question that varying conditions between plots could affect draft, but it fails to make a connection with the inability to distinguish between treatment effects (how the hitches affect draft) and the difference between the two plots.

Sample: 5C
Score: 2

This essay correctly identifies the draft as the response variable and plowing with the two different hitches as the treatments, but it incorrectly identifies the hitches as the experimental units. Part (b) recognizes the random assignment of plots to hitches. Part (c) states that there was no replication in the study but does not clearly explain the basis for that conclusion. In part (d) the essay indicates that changing conditions in the plots can affect draft, as stated in the first paragraph of the question, but does not make a clear connection to the inability to distinguish between treatment effects (how the hitches affect draft) and the difference between the two plots. The phrase “hinder the results of the study” does not provide sufficient clarity. This essay indicates some confusion about the treatments and experimental units, and the level of communication is not strong.