Please help - an elephant is eating all of our sunflower seeds!

Overview:
Students will learn about designing experiments through an activity in which students have been recruited to help solve a mystery about an elephant breaking into stores and eating sunflower seeds. From the evidence provided, students must determine if there is a pattern as to which store the elephant goes and raids each night. Students should generate a hypothesis and design an experiment to test it. This activity is based on a study entitled, "Elephants have a nose for quantity," that examined elephants' ability to identify larger quantities based on olfactory cues.

Goal(s): Students understand the basic principles of the scientific method, specifically with regard to animal behavior research.

Objective(s):
1. Students understand terminology of the components involved in an experiment (hypothesis, dependent variable, independent variable, constant, control).
2. Students demonstrate their understanding of these components by designing an experiment.
3. Students are able to evaluate the experimental designs of classmates and of a real world experiment.

Materials:
- Student packet containing – recruitment letter, map of Baan Klang, data reports from 4 stores
- Research Methods worksheets – self and other
- Research Methods worksheet other, Teacher version

Procedure:
Present students with the letter from the Mayor of Baan Klang, seeking their assistance in solving the mystery of the sunflower-eating elephant.

Have students break into groups and review the materials they have received – the letter, map, and data reports from the 4 stores. Students should identify what they know and what they think is happening. If students have an idea, they must present evidence to support their idea. If others disagree with a student's idea, they too must present evidence to counter.

Some ideas students may have and counter arguments (evidence against):
- Raid seems to happen if store has >300 kg
    - Counter: Some raids happened with quantities less than 300 kg. For example, 11-Jan, Store #4 was raided with 260 kg.
- Elephant hears or sees the delivery and will raid the night after a delivery

    - Counter: Some raids happened when the store did not receive a delivery (the quantity was the same 2 days in a row). For example, Store #2 had 240 kg of seeds on both 12-Jan and 13-Jan, so a delivery was not made on 13-Jan as the amount of seeds did not increase. Regardless, Store #2 was raided the night of 13-Jan.
- Elephant will raid when a delivery was not made that day (perhaps for safety reasons)
    - Counter: Several raids occurred the day that a delivery was made (i.e. the quantity increased from the day before). For example, 8-Jan, Store #1 was raided and they had received a delivery that day (i.e. the quantity of seeds increased from the day before).
- Elephant will select the store that is closest to them/closest to the forest/not in town
    - Counter: Raids have happened at all 4 stores. Some of the stores are not near the national forest and would require the elephant to walk by the other store(s) to raid one in particular. For example, 09-Jan, the elephant raided Store #2, which is in the village. Store #3 is closer to the forest, which would not require going into town, but Store #3 only had 120 kg of seeds that night whereas Store #2 had 240 kg.

Give students time to work with the data reports and determine that the elephant is raiding the store that has the largest quantity of sunflower seeds that day, regardless of location.

Discuss with students how they think this might be happening – how would an elephant know which store had the greatest quantity of seeds?

Students must then generate a hypothesis as to how the elephant might be able to do this. They will then need to design an experiment that would test their hypothesis. This could be done as a whole class or in small groups, with each group generating their own hypothesis and then designing their own experiment.

> *Note*: the study this lesson is based on determined that elephants were able to use olfactory cues to determine quantity differences. Some students may have other hypotheses that do not involve olfactory cues. As long as there is no evidence in the above example that would refute their hypothesis (such as the elephant hearing a delivery and raiding that evening), you could let the students move forward and design an experiment based on their alternative hypothesis as the process is the same – they will design and identify all components of their experiment.

Guiding students through this process of designing their experiments, the instructor should identify and make sure the students understand the different components of an experiment: dependent variable(s), independent variable(s), controls, constants, conditions. If they are not already familiar, it is good to walk through an example. Below is an example of which students of various ages and levels should be able to readily identify several of the different

components. Instructors can adapt this activity to the level of their own students and only include the components that the children will understand.

Example experiment:

- Some people believe that their tomato plants grow better if classical music is played to them. Is that true? Let's design an experiment to find out.
- Here is the research question: Do tomato plants grow better if classical music is played to them?
- Let students generate some possible hypotheses.
    - Options:
        - No difference
        - Music makes them grow better
        - Music makes them grow worse
    - Select one hypothesis
- Variables – independent and dependent. Ask students to explain/define these (if they know), and then brainstorm what those variables could be for this experiment
    - Independent variable – something the experimenter changes; not affected by other changes happening
    - Dependent – what is being measured; changes when something around it changes
    - Have students brainstorm some ideas for what the independent variable should be and what some dependent variables should be
        - Independent variable – sound type (classical music, no music/noise, other music type)
    - In thinking about the dependent variables, have students think about the research question and what is meant by 'better' – how do we measure what is 'better'?
        - Dependent variables – height of plant, number of tomatoes on the plant, size of the tomatoes, number of leaves on the plant, color/overall health of the plant, etc.
- Conditions – different types of conditions the plant is put under to test
    - Based on what discussed thus far, the 3 conditions are: classical music, other music, no music.
    - No music is the control – in this case the control is where there is no change in a variable, the experimenter is not manipulating/changing something about the condition. Other controls are conditions that test for alternative explanations.
    - Discuss why it is important to have a few different conditions and control(s). Why would we include a condition where another type of music would be played?
    - Note: there can be other conditions, these are just 3 examples
- Constants – things that stay the same between the different conditions

- Have students brainstorm what these should be. Also discuss why these things are important – why make sure these things stay the same between different conditions?
- Possible examples of constants: size of pots, amount of soil, amount of water, timing of watering, amount of sunlight, temperature, planted in the same way, timing of feeding (fertilizing), amount of fertilizer, number of plants grown in each condition, measurements taken on the same day, how loud the music is that is played to them, duration and frequency of the music, etc.

After students have reviewed and understand the different components of experiments, they should work on designing their own, making sure to use the proper terminology. The 'Research Methods worksheet – self' can be used to help students in the design process. Again, this sheet can be modified based on the level and ability of the students to only include particular components.

Once students have designed their experiments, have them present them to the group and discuss.

- Does everyone agree with how the experiment was designed?
- Are the different conditions appropriate?
- Is there a control condition (or multiple)? Are they appropriate?
- Are there other possible conditions?
- Other dependent variables?

After groups have shared and discussed their experiment ideas, the instructor should then tell students about the real research study that was conducted examining elephants' ability to select the larger quantity of sunflower seeds through smell. A description of the study is below. Read through beforehand to determine how to present the study to the students. Students can identify components of the research study by filling out the 'Research Methods worksheet – other'. (Teacher version provided)

Overview of the study:
Many species are able to tell the difference between 'more' and 'less', and use that information every day to make decisions. For example, someone looking at two bags of candy with the same price at the store, noticing that the bag on the right has more pieces than does the one on the left, decides to take the bag on the right. The person was able to tell just by looking at the two bags which one had more. The difference between the two bags must have been noticeable enough that the person was able to determine this without actually counting each piece of candy. When the items are few (e.g. comparing 2 items to 3 items) or the difference between the two quantities is large (e.g. comparing 147 pieces of candy to 294 pieces), people,

and other animals such as monkeys, birds, and dogs, can make these decisions quickly and easily.

The researchers of the study were interested in whether Asian elephants were able to tell the difference between two different quantities by using olfactory cues. While elephants do use vision, they primarily rely on their senses of smell and hearing. Therefore, the researchers decided to present two buckets that held different amounts of sunflower seeds to an elephant, let the elephant smell the contents of both, then let it pick one of the buckets to be able to eat what was inside.

For each trial of the experiment, researchers pushed a table with 2 plastic buckets forward toward the elephant. The buckets had lids that were attached so the elephant could not remove the lid and get what was inside, but the lid did have holes in the top so the elephant could smell what was in the bucket. Once the elephant had smelled the 2 buckets, the researchers would pull the table back, unclip the tops of the buckets, and replace the "holey" lids with solid, upside down lids. The table was then pushed back toward the elephant so the elephant could select one of the buckets by sliding off one of the lids and eating what was inside. Once they ate it, the table was pulled back so that they could not try to eat what was in the other bucket.

Six elephants participated in the study – 4 females and 2 males, ranging in age from 12 to 45 years old.

The elephants were familiar with the table and bucket set up and procedure from tasks they had done previously. In those tasks, however, they would be presented with food only in one bucket, not both. In this experiment, food was in both containers.

The researchers presented different quantity combinations to the elephants to see if they could tell the difference between two quantities if the difference between the two quantities was small versus large. For example, 4 g vs 24 g is a large difference, while 8 g vs 12 g is a smaller difference. **Note: Can ask the students what they think will happen. Will the elephants be able to do this?*

Below are the different conditions presented to the elephants, both in training and testing. You can ask the students why they think each of these conditions were presented (the rationale provided by the researchers is in parentheses). You can also ask students if they have ideas of other conditions that could have been presented and why. Again, only include information/conditions that are appropriate for the level of the students.

Training conditions:

- 4g seeds vs none

    - Rationale: make sure the elephants could recognize this amount (4 g) and would select it over a bucket that had nothing
- Solid-lid condition – 24g vs none, lids did not have holes
    - Rationale: make sure the elephants were not picking up on some other, non-olfactory cue
    - They should not be able to get olfactory information if the lids are solid, therefore they should select the buckets at random/chance
    - If they do well on this, then the elephants are using some other cue to solve the task
- One ratio – 4g vs 32g
    - Rationale: make sure the elephants understood that both buckets could have food
    - Since they had not performed tasks where both buckets had food, this was to make sure the elephants knew there was food in both buckets and they could select either. The ratio (difference between the 2 quantities) was large, so if they were able to determine which one had more, they should select the bucket with 32 g more often

Experimental trials – two-quantity conditions:

- Various ratios – compare smaller and larger quantities against one another, such as 4 g vs 8 g, 12 g vs 24 g)
    - Rationale: if the elephants can determine quantity via olfactory information, they should select the bucket that has the greater quantity of sunflower seeds more frequently.
    - The researchers also examined whether the elephants did better when the difference between the two quantities was large versus when the difference was small.

Additional conditions (controls):

- Using metal buckets instead of plastic
    - Rationale: in case there were any residual olfactory cues remaining on the plastic
- Experimenters pushing the table did not know which bucket had more or less.
    - Rationale: in case the researchers were providing any cues to the elephant about which bucket to select.
- Residual odor check – 14 g vs 14 g in buckets that previously had other quantities
    - Rationale: if olfactory information remained on the plastic buckets and elephants used this information, it would interfere with their performance in the experimental trials; therefore, if they did not perform well in the experimental trials, this condition would help determine if residual odors on the buckets was causing an issue.

Additional information:

- In training only, elephants performed sets of 12 trials until they got 80% correct on a set – i.e. got 10 out of 12 trials correct during that set.
- Researchers recorded which bucket the elephant selected (left or right) and if this was 'correct' or 'incorrect'
- Location of the correct bucket (the one that had 'more') was pseudorandomized using the following criteria:
    - the left and the right bucket were both correct in 6 out of the 12 trials within a set
    - the correct location could not be in the same location (right or left) more than 3 trials in a row

Findings:
Researchers found that on the experimental trials, elephants performed well in selecting the bucket that had the larger quantity of food. They were also more likely to select the 'correct' bucket when the difference between the two quantities was high compared to trials where the difference between the two quantities was small.

Solid lid condition – elephants selected the correct bucket an average of 12 out of 24 trials; chance is 50%

- Since performing at chance, they were not receiving olfactory or other cues that would allow them to solve the task. Therefore, seems likely that they were using olfactory cues to solve the task on the other experimental trials where olfactory information was provided.

Metal bucket condition – performed same as other experimental trials

- Since performing same as experimental trials, they were not using lingering, residual odor information on the plastic buckets

Residual odor check – elephants selected the correct bucket an average of 12 out of 24 trials; chance is 50%

- Since performing at chance, they were not using residual odors from previous trials

Discuss why this research is important and how it can help contribute to conservation efforts.
This study helps researchers better understand how elephants may be making foraging decisions in the wild – they likely decide where to go for food based on long-distance olfactory information and, to maximize their effort, will want to select a location that has a large payoff. In some settings where elephants and humans live in close proximity to one another, such as what was presented in the hypothetical story, elephants will raid crops or food stores. The humans often then suffer major monetary losses when their crops are raided. This situation puts humans and elephants in great danger of being harmed by one another as farmers may attempt to defend their crops from elephants that are much larger than themselves. It may be

possible to develop a way in which olfactory information can be manipulated so as to send elephants away from human crops or direct them to safer areas.

Extend the lesson:
Have the students try this experiment themselves. Have opaque cups or buckets that have lids with holes in them. Put two different quantities of sunflower seeds, or another food item, in the containers and have students smell them to see if they can determine which has more. Can present different quantity combinations as was done in the study with the elephants. Can also present the same task to the students but have them look inside the containers and see if they can perform the task. Discuss why this is easier – humans rely primarily on sense of vision, so can readily perform the task using vision, but not using smell.

Dear Super Sleuths,

We are contacting you to see if you can help us solve a mystery. The officials here do not know what is going on and are at their wits' end. It has been suggested that you are quite skilled at solving mysteries and therefore, we ask for your assistance.

We have been receiving calls about elephants raiding merchants' stores for the last couple of weeks. Every shop owner reported the same thing – during the night, an elephant has broken in and eaten all of the sunflower seeds. As you know, it is sunflower harvesting time and stores are receiving regular shipments of the seeds and therefore tend to have large quantities on hand. Well, at least they did until the elephant ate all of them!

Before the officials can figure out a solution to the situation, they first need to figure out what exactly is happening – what store is the elephant going to and why. This is where we need your help.

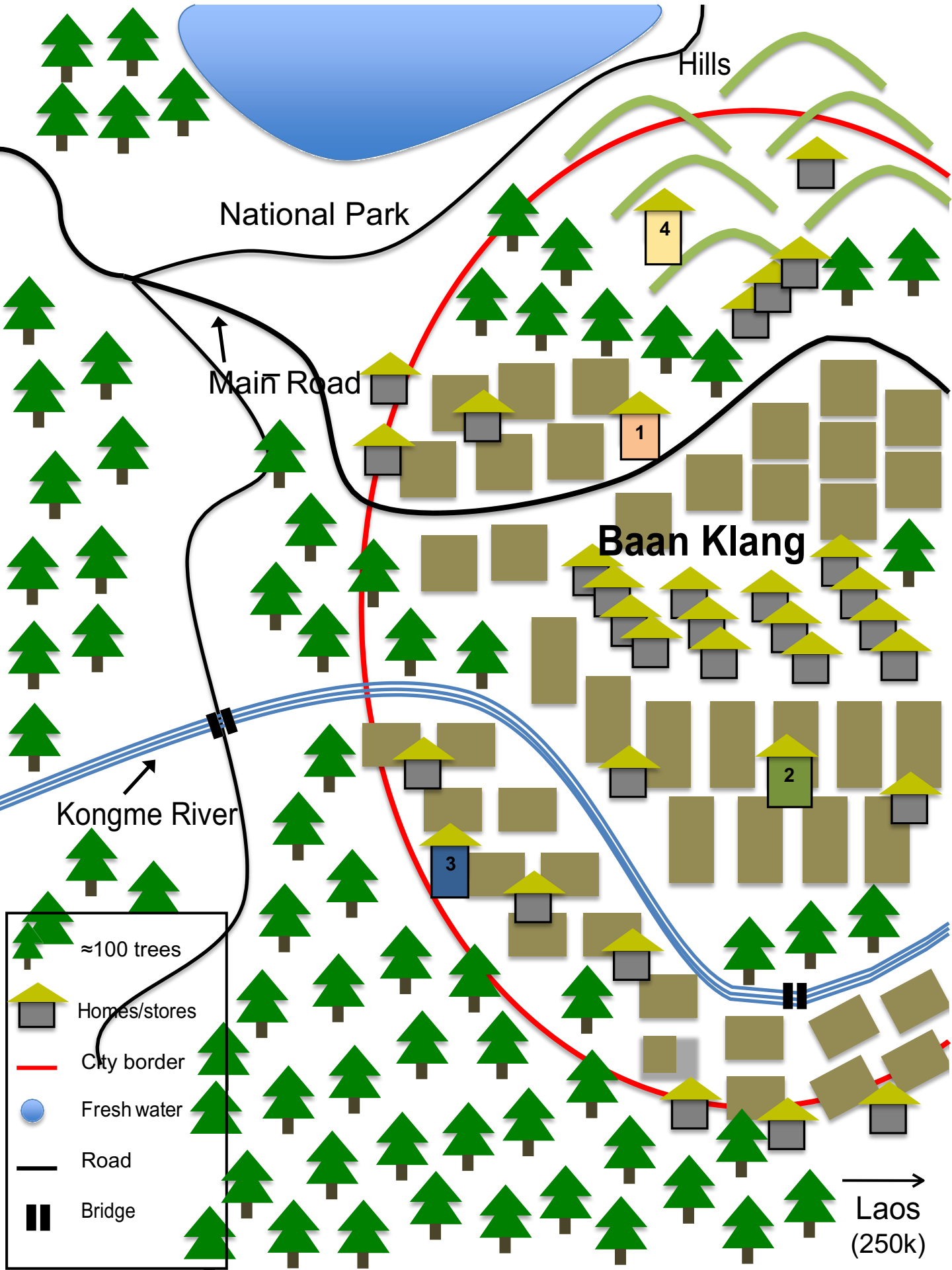
We are providing you with a map of the area that shows where each of the stores who have reported being raided are located in relation to the national park where the elephant is likely coming from. In addition, officials asked for the 4 stores to turn in records of the previous 2 weeks that had the following information: date, amount of seeds (in kg) recorded in the morning, and if an elephant raided the store later that evening (yes/no).

Hopefully you will be able to determine if there is a pattern to where the elephant is going each night. If so, the officials will then be able to start working on a solution. We look forward to hearing from you soon.

Sincerely,

Mayor Srisuk

Mayor Srisuk
Mayor of Baan Klang


Hills
National Park
Main Road
4
1
Baan Klang
2
3
Kongme River
≈100 trees
Homes/stores
City border
Fresh water
Road
Bridge
Laos
(250k)

RECEIVED

Store # 3

Date	Amount (kg)	Raided (Y/N)
7-Jan	320	Y
8-Jan	0	N
9-Jan	120	N
10-Jan	300	Y
11-Jan	0	N
12-Jan	80	N
13-Jan	120	N
14-Jan	200	Y
15-Jan	0	N
16-Jan	80	N
17-Jan	240	Y
18-Jan	0	N
19-Jan	60	N
20-Jan	120	N
21-Jan	240	Y

Date reported: 30-Jan

Store # 4

RECEIVED

Date	Amount (kg)	Raided (Y/N)
7-Jan	40	N
8-Jan	160	N
9-Jan	180	N
10-Jan	200	N
11-Jan	260	Y
12-Jan	0	N
13-Jan	120	N
14-Jan	180	N
15-Jan	260	Y
16-Jan	0	N
17-Jan	100	N
18-Jan	280	N
19-Jan	300	Y
20-Jan	0	N
21-Jan	80	N

Date reported: 24 JAN

Store # 1		
Date	**Amount (kg)**	**Raided (Y/N)**
7-Jan	200	N
8-Jan	320	Y
9-Jan	0	N
10-Jan	200	N
11-Jan	200	N
12-Jan	260	Y
13-Jan	0	N
14-Jan	160	N
15-Jan	200	N
16-Jan	300	Y
17-Jan	0	N
18-Jan	120	N
19-Jan	280	N
20-Jan	280	Y
21-Jan	0	N

RECEIVED

Date reported: 27-Jan

RECEIVED

Store # 2		
Date	**Amount (kg)**	**Raided (Y/N)**
7-Jan	120	No
8-Jan	240	No
9-Jan	240	Yes
10-Jan	0	No
11-Jan	200	No
12-Jan	240	No
13-Jan	240	Yes
14-Jan	0	No
15-Jan	40	No
16-Jan	160	No
17-Jan	220	No
18-Jan	340	Yes
19-Jan	0	No
20-Jan	120	No
21-Jan	220	No

Date reported: 28 JAN

Name: _____

RESEARCH ELEMENT	ASK YOURSELF…	NOTES
Research Question	**What do you want to know or find out?**	
Hypothesis	**What do you think will happen?**	
Design	**How will you test your hypothesis?**	
Independent variable	**What are the things that you would manipulate/ change?**	

Dependent variable	**What would you check to see if the response was different?**	
Constants	**What are the things that would be kept the same for all trials and subjects?**	
Control(s)	**Is there a group that will not have the manipulation or conditions that will test alternative explanations?**	

Name: _____

Title of research study: _____

RESEARCH ELEMENT	ASK YOURSELF…	NOTES
Research Question	**What did they want to know or find out?**	
Hypothesis	**What did they think would happen?**	
Design	**How did they test their hypothesis?**	
Independent variable	**What were the things that they manipulated/ changed?**	
Dependent variable	**What did they check to see if the response was different?**	

Constants	**What were the things that were kept the same for all trials and subjects?**	
Control(s)	**Was there a group that did not have the manipulation or conditions that tested alternative explanations?**	
Results	**What did they find out?**	
Conclusion	**Did the results *support*, *not support* or *refute* the original hypothesis?**	

Discussion Question: What does this research tell us about how animals behave, and how could it be applied to the conservation of the species?

Name: _____

Title of research study: _____

RESEARCH ELEMENT	ASK YOURSELF…	NOTES
Research Question	**What did they want to know or find out?**	Can elephants determine different quantities of food using olfactory cues? Can elephants select a quantity that is 'more' over a smaller quantity?
Hypothesis	**What did they think would happen?**	Hypothesized that the elephants would be able to determine quantity differences based on olfactory cues. Elephants would be able to select which had 'more.'
Design	**How did they test their hypothesis?**	Presented 2 buckets to elephants that had different amounts of sunflower seeds in each bucket. The buckets had attached lids with holes in them so that the elephant could smell what was in the bucket. Elephants would smell the two buckets, after which the buckets would be pulled back, and the lids removed and replaced with solid, unlocked lids. The buckets were the re-presented to the elephants again so that they could pick one and eat the contents inside. The two quantities inside the bucket varied in terms of overall size and the difference between them.
Independent variable	**What were the things that they manipulated/ changed?**	Quantity of sunflower seeds in the two buckets
Dependent variable	**What did they check to see if the response was different?**	Whether the elephant selected the right or the left bucket, the correct or incorrect bucket ('correct' being the one that had 'more')

Constants	**What were the things that were kept the same for all trials and subjects?**	2 researchers, pushing table toward and away from elephant, 12 trials per set, left and right buckets were both 'correct' 6 out of the 12 trials
Control(s)	**Was there a group that did not have the manipulation or conditions that tested alternative explanations?**	Metal buckets Naïve researchers (the 2 people pushing the table did not know which bucket was correct) Residual odor check – same quantity in each, buckets previously held different quantities
Results	**What did they find out?**	Elephants performed well in selecting the bucket that had the larger quantity of food. They were also more likely to select the 'correct' bucket when the difference between the two quantities was high compared to trials where the difference between the two quantities was small.
Conclusion	**Did the results *support, not support* or *refute* the original hypothesis?**	Results supported their hypothesis

Discussion Question: What does this research tell us about how animals behave, and how could it be applied to the conservation of the species?

This study helps researchers better understand how elephants may be making foraging decisions in the wild – they likely decide where to go for food based on long-distance olfactory information and to maximize their effort, will want to select a location that has a large payoff. In some settings where elephants and humans live in close proximity to one another, such as what was presented in the hypothetical story, elephants will eat crops or where food is stored. The humans often then suffer major monetary losses when their crops are eaten or destroyed. This situation puts humans and elephants in great danger of being harmed by one another as farmers may attempt to defend their crops from the elephants, which are considerably larger than humans. It may be possible to develop a way in which olfactory information can be manipulated so as to send elephants away from human crops or direct them to safer areas.