Inferences in the Classroom and Everyday Life

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For many years science educators have advocated that inquiry skills should be an essential outcome of science instruction (Welch, Klopfer, Aikenhead & Robinson 1981). These skills include observing, classifying, measuring, predicting, inferring, forming hypotheses, interpreting data, collecting variables and experimenting (Cain & Evans 1984). Inferring is not only a basic skill in science and mathematics (Agin 1979; McGalliard & Cooney 1979), but also a process that is fundamental to interpreting events in our everyday lives (McGalliard & Cooney 1979). Although inferring is included in certain science curriculum programs from the elementary grades (Gallagher 1979) to the university (Medve, Pugliese & Barr 1985), nearly 40 percent of 17-year-olds cannot correctly draw inferences from written material (Kormondy 1985).

The purpose of this article is to encourage teachers at all levels to utilize inference activities in their science classes. Although most of the included examples are biological and intended for secondary students, teachers can modify these examples to fit their individual classrooms.

What Are Inferences?

Inferring is such a common activity that we are often not aware of using this inquiry skill. For example, if you smell smoke, you infer that something is burning. If you see a small deer standing next to a larger, anterless deer, you infer that the larger deer is the mother of the smaller deer. If you see a student looking in the direction of another student's exam, you infer that the student may be cheating. In each of these examples the inference is a logical conclusion reached by reasoning. In each case, however, the inference may not be true because inferences are tentative, and additional observations may refute what has been inferred.

> *"Inferring is not only a basic skill in science and mathematics, but also a process that is fundamental to interpreting events in our everyday lives."*

Scientists often use inferences in their research. Fleming's first observations of the bacteria-free zone around *Penicillium notatum* surely must have triggered the inference that a substance in this zone was inhibiting or killing the bacteria and that the substance was probably produced by the mold.

In another example, botanists puzzled over the source of nutrition for the achlorophyllous plant known as Indian pipe. Observations revealed that fungal hyphae connected the Indian pipe roots to the roots of neighboring trees. Based on these observations, an inference was probably drawn that Indian pipe obtained its nutrition indirectly from the tree. Injecting P_{32} into the phloem of the tree showed showed that the P_{32} appeared in significant amounts in the Indian pipe. This provided another observation to support the tree nutrition inference. Placing a metal sheet vertically in the ground between the tree and the Indian pipe resulted in the death of the Indian pipe and provided more supporting evidence. Finally C_{14} was incorporated into carbohydrates in the tree and was found to be translocated to the Indian pipe via the fungal hyphae. In this example additional observations supported the inference that the Indian pipe indirectly obtains its nourishment from a neighboring tree.

Consider this example that many biology teachers have experienced. One of the *Allium* root tip slides is missing. A check of the microscopes reveals that the missing slide is on the stage of microscope number 8. According to the seating chart for the last class, this microscope was assigned to Mary. Based on these observations, it is inferred that Mary left the *Allium* slide on the microscope stage.

Process of Inferring

Inferring depends heavily on sequencing. The first step of this sequence is to make observations. These observations must be accurate and quantitative, and utilize as many of the senses as possible. Observations are accepted as true statements and form the basis of the reasoning activities that follow. The second step is to logically associate the observations into some type of stepwise relationship. From this relationship will develop the third step; the formation of a conclusion. This conclusion is not a restatement of the observations, but instead, is a statement of nonobservable properties that result from logical reasoning of associations of the observations. An inference, therefore, is a conclusion that is arrived at indirectly (Cain & Evans 1984) and is a judgment about nonobservable properties of an object or event (Molitor & George 1976).

In some situations where observations are lacking, it may be necessary to accept arbitrarily certain statements as truths without verifying them. These statements are referred to as assumptions. Observations and assumptions can then be interwoven into the logical reasoning step to arrive at a conclusion. The strength of an inference, however, is directly related to the number of observations and the use of assumptions (Table 1). Reasoning entirely from assumptions results in the weakest inference.

Table 1. Relationship between inference strength and the number of supporting observations

All assumptions	Weakest inference
Few assumptions + few observations	↓
Few observations	
Many observations	Strongest inference

Predictions are inferences that forecast a future event. For example, if you hear rumbling, see dark clouds and feel a brisk wind, you may predict that it is going to rain. You have made a prediction by using logical reasoning to develop an inference that forecasts a future event. As with all inferences, however, predictions may not be true.

Let's take a detailed look at an example to see how the process of inferring works. Consider what observations you can make about Figure 1. Certainly a lengthy list of observations could be developed; however, limit your list to those involving the tracks and the holes.

You may have observed that there are: two holes; two sets of tracks at the left hole; one set of tracks at the right hole; tracks at the left hole showing toe prints that are pointed toward the hole; and tracks at the right hole showing toe prints pointed away from the hole. From these observations we may infer that two animals entered the left hole and one animal exited the right hole.

"Inferring is a key inquiry skill."

Let's add to these observations and inferences the observation that the right set of tracks at the left hole is of the same type as the tracks at the right hole. In addition, assume that the two holes are connected and that the similar sets of tracks at the holes were made by the same animal. From these observations, inferences and assumptions, we may now infer that an animal entered the left hole and exited by the right hole.

Assume that the animal that entered the left hole and exited the right preys on animals of the type that entered the left hole and that the predator entered the hole last. A logical inference is that the predator followed the other animal into the left hole, caught the prey in the hole, ate it and exited by the right hole.

Now assume that the predator was unable to find the other animal in the hole. Using this assumption we may infer that the predator followed the other animal into the left hole and exited by the right hole while the other animal remained in the hole.

Assume that the predator will encounter another prey animal such as the one consumed in the hole. What do you predict will happen? There are two possibilities. You could reason that because the predator has just eaten, it will not eat the animal. Making the assumption that the predator is full will help this prediction. You could also predict, however, that the predator will eat the prey. In this case, assuming that the animal is still hungry supports this prediction.

Varying the assumptions will result in different sequences of reasoning and, therefore, different inferences. For example, instead of assuming that the holes are connected, make the assumption that the holes are not connected. Using the same observations one can infer that there are two different animals in the left hole.

Classroom Activities

Scientists frequently make inferences when interpreting data. What inferences can you make from the data provided in Table 2? Some of the inferences you may have arrived at include: 1) more bears were harvested in 1976 than any other reported year; 2) hunting success was the lowest in 1982; and 3) no bears were tagged in 1977 and 1978. See if you can use the data (observations) in Table 2 to organize the relationships and logical reasoning required to state these inferences. You might also consider other

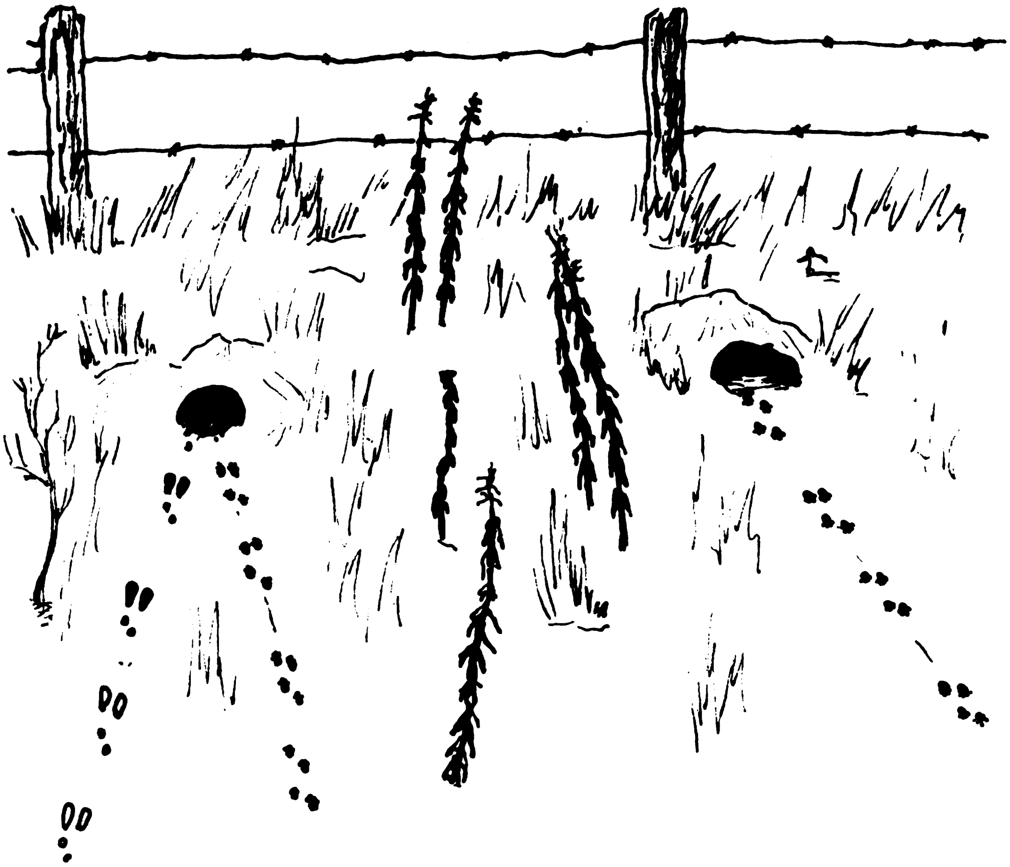

Figure 1. What inferences can be made from this scene?

observations and/or assumptions that would strengthen, weaken or negate these inferences. In so doing, remember that inferences are tentative and subject to change as more observations are obtained that support or refute the inference. In this example, the above three stated inferences, although logical, are in fact all false as determined by examining actual bear harvest records. In order to be true: 1) the same number of bears must have been available for harvest each year; 2) hunting must have occurred every year; and 3) the total harvest must have been in direct proportion to the tagged harvest. Actually, none of these occurred and as a result our inferences are false.

Compose a list of observations from Figure 2. Using logical reasoning relate these observations into an unobservable property. What inferences did you make? Among those inferences that you might develop are: 1) the fish are dead; 2) the water is polluted; 3) there is a foul odor in the air; 4) there is a low level of dissolved oxygen in the water; 5) this event happened recently; and 6) this event occurred suddenly over a relatively short period of time. Certain of these inferences are more sophisticated than others, while others are also conclusions that can be reached after a great deal of reasoning that involves a number of assumptions. See if your students can develop the reasoning sequence to arrive at these inferences. They may need to use some assumptions.

Another classroom activity involves the use of data to form inferences. Consider Figure 3 which shows respiration data collected for a parasite that was exposed to temperatures from 31-41 C. The observations in this case are represented by the points on the

Table 2. Statewide harvest rates of bears tagged in Pennsylvania during the year of harvest (Alt 1984)

Year	*Harvest Rate (%)*
1973	18
1974	21
1975	24
1976	33
1979	22
1980	20
1981	15
1982	13
1983	24
Average	21

Figure 2. Can you make an inference about these fish or the quality of the water?

graph. Can you make an inference about the host of this parasite? If the parasite was exposed to 45 C, can you make a prediction about the respiration rate?

Below are several biological, classroom activities that can be used to practice the inferring process:

1) Observe the teeth of mammals and infer the animals' feeding niches.
2) Observe a variety of leaves and infer the plants' habitats.
3) Observe the beaks and feet of birds and infer their feeding niches.
4) Observe mammals' feet and infer their habitats.
5) Observe a cross-section of a corn stem and infer tissue functions.
6) Observe a variety of fruits and infer the methods of seed dissemination.
7) Observe the arrangement of bones in the knee and hip joints in an articulated human skeleton and infer the range of movement.
8) Observe a cat skeleton and infer the locations of the most essential organs.
9) Observe a bean plant and infer the functions of the organs.
10) Observe a variety of flowers and infer the methods of pollination.

As mentioned previously, inferring is a common activity that permeates our daily lives, even though we often are not consciously using this inquiry skill. Advertisers are very aware of this and as a result have developed numerous slogans which place the consumer in a position to infer. For example, what inferences are arrived at with respect to each of the following advertising slogans?

"Nobody sweats the details like GM."
AT & T. "The more you hear, the better we sound."
"Safeguard is always the smallest soap in the house."
The Travelers. "Fairness is good business."
Timex watches. "They take a licking and keep on ticking."
Kodak film. "Because time goes by."
United States savings bond. "Take stock in America."
Michelin. "Because so much is riding on your tires."

In each instance most of us infer, consciously or unconsciously, what the advertiser intended.

Using stereotype categories or trendy expressions also requires inferences to be made. What inferences come to mind when you encounter the following remarks?

"He is a real James Bond type."
"She is a real brain."
"That guy is a shark."
"What a computer head."
"He's a real cool stud."

Individuals may infer something different when hearing or using these expressions. Our inferences are based on the observations from which we developed the logical reasoning sequence and everyone does not start with the same set of observations. Based on the James Bond movies you have seen or which of Ian Fleming's books you have read, or who was playing 007, your inference of a "James Bond type" may be different from that intended by the user of the phrase.

Another example of an inference involves a situation that many people have experienced, directly or indirectly. Your son or daughter has just put on hightop sneakers, picked up a basketball and walked past you toward the door. You ask, "What are you going to do?" The disgusted sounding answer being, "I'm going to play basketball. Can't you see that?" Sound familiar? Your child was upset because you did not make the inference: hightop sneakers + basketball = playing basketball. Of course, you may have the correct inference, but simply asked the wrong question. Did you really intend to ask, "Where are you going to play basketball?"

Certainly an objective of education is to develop in every individual the ability to solve problems intelligently. This requires that our graduates be, among other things, knowledgeable with respect to how "sciencing" is done. Their ability to apply the processes of science, or utilize inquiry skills, might be one of the greatest benefits to be obtained from an education. Inferring is a key inquiry skill. It is, therefore, essential that everyday examples of inferences be included in formal coursework.

What follows are examples of everyday situations where "sciencing," specifically, the inquiry skill of inferring, can be applied. Put yourself in the position of observing a young man walking toward you, but at a distance. You notice he is wearing a red letter-jacket with black sleeves. As he approaches you note in sequence that: 1) the letter on the jacket is a B; 2) the year on the jacket is 1986; and 3) several small football pins are located immediately under the letter. This situation illustrates that, as more detailed observations are obtained, one is in a position to infer more critically and with a greater degree of confidence. In this example, these inferences sequentially include that the young man involved: 1) attends or attended a high school; 2) is a 1986 graduate of high school B; and 3) played football. It is important to emphasize again at this point that inferences drawn from observed data are tentative (McGalliard & Cooney 1979). Additional observations will support or refute these inferences. It should also be apparent in this example that we have assumed the jacket belongs to the young man. To do otherwise would, of course, require drastic revisions in our inferences.

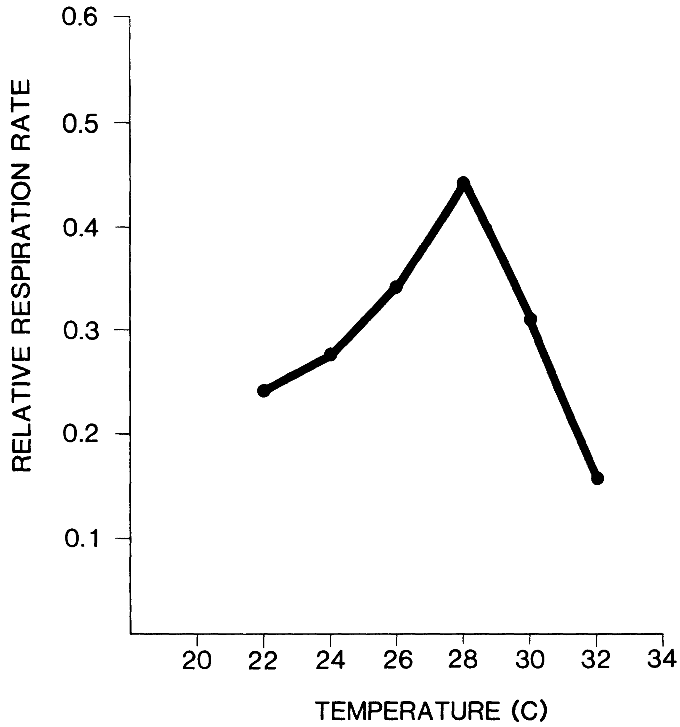

Figure 3. Effect of temperature on the relative respiration rate of a parasite.

You are shopping in a local grocery store and notice that Brand X hand soap is available in packages containing four bars. Each package is being sold at a price which is comparable to purchasing three bars of soap manufactured by other companies. The initial inference in this instance is that you are getting more for your money by purchasing Brand X. However, upon close inspection of the various brands of soap it becomes apparent that the four bars of Brand X weigh approximately the same as three bars of other brands. This is, of course, an example of an everyday situation where an additional observation refutes the initial inference. One might consider different sized boxes of cereals, different sized canned goods, medium versus large eggs, etc., in the same context.

An inference arrived at by many with respect to the annual major league all-star baseball game is that each position on the starting team is filled by the best player in that league for the present year. Upon close inspection, however, it is noted that the starting players are selected by popular fan vote. It is in turn observed that certain of the starting players for both leagues are batting in the vicinity of 0.220 with fewer homeruns and RBI's than other players in the league and several have missed a significant number of regular season games due to injuries. In other instances players were selected for positions they no longer play. This is another situation where an inference must be modified as a result of the accumulation of additional factual information.

Fast food establishments Y and Z are located adjacent to one another. They both specialize in the same types of take-out foods; however, establishment Y is littered while establishment Z is neat and orderly. Several inferences are possible: 1) establishment Y has more business as compared to Z; 2) establishment Z is more particular concerning clean-up operations; and 3) the clientele that frequent establishment Z do not litter to the extent that they do at Y. Time does not permit your determining which of these is true through observation. You, therefore, make several assumptions. First you assume that the customers to each establishment litter to the same extent. Thus, inference #3 is eliminated. In turn you assume that each establishment does approximately the same amount of business. Inference #1 is thus eliminated. It is, therefore, inference #2 which is accepted and on that basis you purchase your lunch from establishment Z. Are you not also inferring that if establishment Z is so particular about the cleanliness of the exterior of their restaurant that they are also conscientious about the quality of their food and the cleanliness of the interior of the restaurant?

Summary

Inferring is one of the basic scientific skills (Agin 1979; McGalliard & Cooney 1979). In our rush to get back to "basics," we need carefully to incorporate these skills into our science classes so that they are an integral part of "sciencing." We must also ensure that applications to everyday, real life situations are more significant to the students. When our students become a part of the work force, not many will be making inferences based on data that they collected while performing an experiment related to their vocation. All, however, will be required to infer when they shop, hear a slogan, read a cartoon, engage in conversation, or listen to a presidential candidate say, "There you go again."

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