Learning Critical Thinking Through Astronomy: Frameworks

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STUDENT NOTE

PLEASE DO NOT DISTRIBUTE THIS DOCUMENT.

Contents

Questions

How do scientists know which questions have reasonable answers and which do not? How do frameworks affect our use of imagination or creativity? If you take someone else's invention, change the way it works, and start selling it as your own invention, can you give it the same name or should you change the name?

Materials Needed

For this activity, you will need the following materials:

- a pencil (do not use ink)
- the ability to read and follow directions

Points To Remember

Unless otherwise explicitly instructed, your responses must not contain personal opinions. All of your responses must be in the form of complete sentences; the fewer sentences the better. Spelling and grammar must be correct. Effective communication is essential for both learning and doing science.

Don't ask instructors for answers to questions posed in activities; you won't get them. You may ask questions regarding the clarity of the instructions or the soundness of your reasoning. If you encounter a word you are not familiar with, don't ask the instructor about it. Look it up first in your glossary and then a dictionary or some other source if necessary. Ensure that all definitions are unanimously agreed upon before proceeding. There are, of course, sound reasons for these policies. See the instructor if you have questions, but do not complain about these policies. They are not negotiable.

1 Simulating Nature

In this activity, the instructor will play the role of Nature. Remember that Nature isn't an actual person and thus cannot talk. So questions asked of Nature will go unacknowledged. Your instructor, however, hears every question you ask so don't think you are being ignored.

Nature will come around to each table and allow some natural phenomenon to happen. Nature will do this several times for you so you can begin the process of completing your task, which is described in the next section. After a few occurrences, Nature will leave you and your colleagues alone so you can work. You can, however, summon Nature to your lab for another occurrence of the phenomenon you're studying. Your instructor will demonstrate how to summon Nature to your lab.

INSTRUCTOR NOTE

This activity usually involves sets of five white dice, but to make things interesting, and more difficult to figure out, use colored dice, or multisided gaming dice, and invent new rules that change the basic rules. I have a dice set with yellow, green, red, and pink dice (ten of each, but that's not important). I also have some gaming dice. So, for example, red dice may count as a direct addition to the number of petals given by white dice. Green dice may count as a subtraction from the number of petals given by white dice. Pink or yellow dice may count as white dice. A d10 gaming die may negate everything and make the result zero. You can make up rules on the fly to illustrate the fact that we never know what Nature has in store for us and that our frameworks are never truly complete. Be sure to be consistent with your rules during each class period.

1.1 Where To Begin?

Your task is to create a set of rules from which you make predictions. Specifically, your goal is to predict what Nature will "say" the next time the natural phenomenon you are studying occurs.

1. As you observe this natural phenomenon, start making a list of the rules you think you may be able to use in predicting what happens in the next occurrence of this phenomenon.

Response

1.2 Collaboration

Scientists rarely work alone. We often collaborate with other scientists. One of the most important reasons for this is to check up on each other. We make sure our collaborators don't overlook something simple that causes their (or our) observations to be incorrect. If we're observing a phenomenon for the first time, it's impossible to know whether our observations are correct or incorrect unless we check against other scientists' observations. As you might expect, one comparison is not enough; repeated comparisons are almost always needed. Take some time now to collaborate with other groups and come to a unanimous consensus on the set of statements you derived above. You may need to modify one or more of your own statements. Don't worry about the concepts of "right" or "wrong" because you have absolutely no way of knowing which you are at this point.

|——— CHECKPOINT ———|

1.3 Now you have a framework!

The **set of rules you derived** constitutes a *framework* that, among other things, defines how you would teach someone else (from another class, for example) to predict what Nature will do. Frameworks let you do much more though. A framework may also be called a *paradigm* (pronounced to rhyme with "time"). We will continue to use *framework* in this course.

2 Accommodating People

2.1 Let's be fair and balanced.

2. If necessary, modify your framework so that it is as fair and balanced as possible.

Response

3. If necessary, modify your framework so that it is as liberal as possible and does not offend someone who identifies as "liberal." If no changes are necessary, explicitly say so.

Response

4. If necessary, modify your framework so that it is as conservative as possible and does not offend someone who identifies as "conservative." If no changes are necessary, explicitly say so.

Response

5. Now, stand back and think for a minute. Why were you asked to even consider modifying your framework to accommodate fairness, balance, and perceived offense? Think deeply about this. Think about another framework with which you are already familiar (like the rules of a game you know). Are the rules fair? Are the rules of chemistry fair? Are the rules of arithmetic fair? Are the rules of algebra fair? Are the rules that govern sunrise and sunset fair? Do these questions even require a scientist's attention? Are these questions of cultural significance? In other words, would the issue be different for non-scientists than for scientists? Should it be? What if the framework (rules) contradict one's personal world view, religion, political world view, or ethical doctrine? Comment on all of this.

Response

6. Why do you think you were asked the previous question? Were they merely hypothetical or have you seen real examples in your own experiences?

Response

STUDENT NOTE

If answering any of these questions made you uncomfortable, angry, or evoked any other emotion, you must not let that emotion guide your thinking and attitude toward this activity. The fact that you recognize that emotion indicates that you are aware of your thinking. Beyond that, how, if at all, you react to that awareness is entirely your responsibility. This activity is not intended to attempt to change your mind about anything, but if that happens as a side effect becoming aware of new facts or certain realities, then that is your responsibility. Embrace the discomfort and use it for metacognition.

|——— CHECKPOINT ———|

2.2 Prediction versus Discovery

7. Do you perceive a difference between a *prediction* and a *discovery*? If so, articulate it. Consider this real example. The *Higgs boson* (a fundamental particle) was predicted to exist in a scientific paper published in 1964 (a copy of which is outside your instructor's office door). The particle's existence was confirmed in July 2012. Think about whether or not the confirmation was expected or unexpected given the prediction from 1964.

Response

2.3 Frameworks let you experiment.

Experiments are situations in which you have some degree of control over the environment in which the phenomenon takes place. Suppose you have a hunch, based on your framework, about the next outcome. Now, experiments must have predictable outcomes. Carry out your experiment by setting up a situation where your test can be carried out and observe what happens.

8. Did you observe the predicted outcome?

Response

2.4 Frameworks don't limit us.

It's very important that you understand that a framework doesn't limit your imagination. For example, you could ask you may ask anything you want to ask about what may be the next outcome or about factors that affect the next outcome, but that doesn't mean the question(s) you ask will have answers. Science only deals with questions that have answers.

9. What constraints does your framework put on the questions you formulate about the possible outcomes?

Response

2.5 Frameworks limit us.

Scientists must be creative when attempting to explain natural phenomena. In fact, a creative scientist is more likely to find a correct explanation for a natural phenomenon than an unimaginative scientist. Scientists must also be rational. Just because you can imagine an explanation doesn't mean that explanation is possible or consistent with your framework. All explanations must be consistent with the framework within which the explanations lie.

10. Consider the question, "What would happen if the dice were to change color?" Although your framework doesn't prohibit you from asking this question, why should asking this question probably be avoided?

Response

2.6 A Matter of Ethics

11. If you take someone else's invention, change the way it works, and start selling it as your own invention, can you give it the same name or should you change the name?

Response

3 Inquiry

3.1 Discussion Questions

12. Was collaboration with other research groups beneficial or detrimental? Does avoiding collaboration have significant consequences? Defend your response.

Response

13. Was modifying your framework beneficial or detrimental? Does not modifying it have significant consequences? Defend your response.

Response

14. At any time during this activity, were you able to *prove* that your framework in its present form is correct?

STUDENT NOTE

Recall that once something is *proven*, it need never be investigated again because the outcome is certain to never change.

Response

15. Reread this activity and replace every occurrence of the word *framework* with *theory*.

STUDENT NOTE

At this point you should thoroughly understand the problem with the word *theory*. When non-scientists use this word, they use it as a substitute for the word *hypothesis*. When scientists use this word, they use it as a synonym for the word *framework*.

16. In science, we say that Nature adheres to frameworks. From where did Nature get the frameworks to which it adheres, and that govern natural phenomena? Did they not have to originate somewhere?

STUDENT NOTE

You won't get very far by tracing the origin of the frameworks. Don't ask, "Well from where did the instructor get the frameworks?" Don't ask, "From where the the person who gave them to the instructor get them?" This approach is futile! You'll end up in an infinite regression. "The frameworks have just always been there, they're there now, and they'll be there a hundred million years from now and that's just the way it is." is not the answer either. The answer is also not the same as that tracing the origin of all scientific information back to an attempt to explain an observation. Think carefully about frameworks in general. This is a difficult question, but not so difficult as to be unanswerable! The answer just may not be obvious to you.

Response

17. How do scientists know which questions have reasonable answers and which do not? How do frameworks affect our use of imagination or creativity? If you take someone else's invention, change the way it works, and start selling it as your own invention, can you give it the same name or should you change the name?

Response

|——— CHECKPOINT ———|

18. Map this activity into as many of the elements of thought as you can.

Response

19. Every activity will have at least one standard associated with it.

STANDARD

I can create a framework that describes a natural phenomenon.

4 Feedback

What could be done to make this activity more interesting? Please be honest.

Response