Connecting the Experiments with the Concepts: How to Help Students Develop Written Explanations for Meaningful Learning

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(IQWST- Investigating and Questioning our World through Science and Technology)

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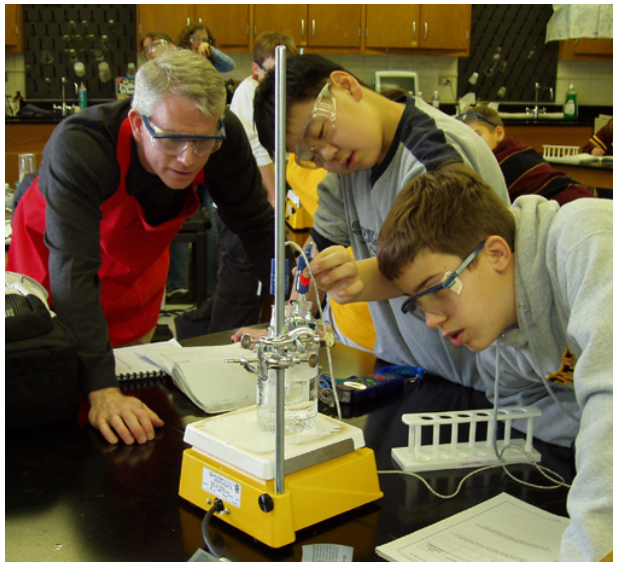


Purpose

- Constructing scientific explanations help students connect the scientific principles to the phenomena.

- Provide science teachers (you) with framework of how to support students in learning how to construct scientific explanations.

Importance of Scientific Explanations

- Scientists develop explanation about phenomena -- it is one of the scientific practices!
- Science education standards (AAAS, 1993; NRC, 1996) advocate environments that support student learning of scientific practices.
- Engaging students in explanation can change their image of science, enhance their understanding of the nature of science (Bell & Linn, 2000) and foster conceptual understanding (Driver et al., 2000).
- Scientific explanations help frame the goal of inquiry as understanding natural phenomenon, articulating and convincing others of that understanding (Sandoval & Reiser, 1997).

Is there enough oxygen to support aquatic animals in the stream?

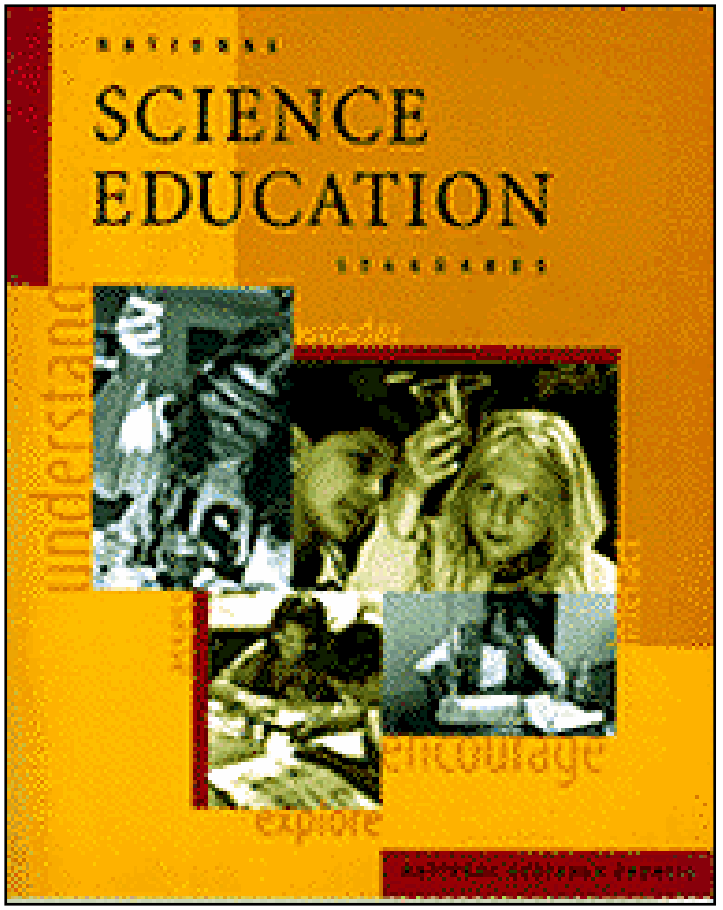
Stream Data	Standards	Excellent/Good-
<u>Dissolved Oxygen</u>: Location A= 110%	Good	water will support life
Location B= 79%	Good	Fair / Poor -
Location C= 94%	Excellent	problems with water quality
Recent rain; High stream flow; Dead cattails at B		

**Flowing water captures oxygen*
**Organic waste causes oxygen depletion*

Write an explanation that a scientist might write that answers the question, "Is there enough oxygen to support aquatic animals in the stream?"

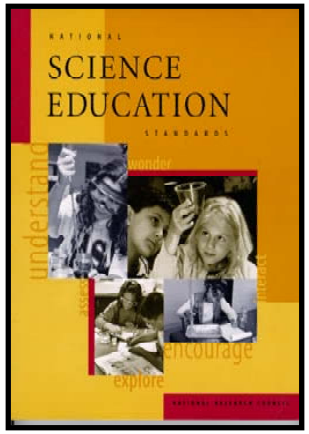
Why Scientific Explanations?

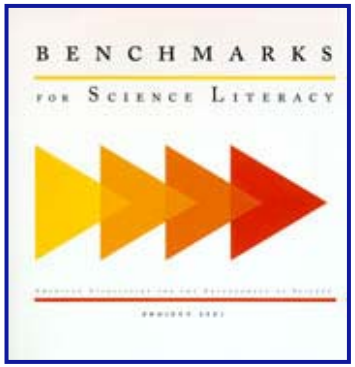
Stressed in National Science Education Standards!



Change Driven by National Standards

"**Inquiry** into authentic questions generated from student experience is the central strategy for teaching science. Teachers focus inquiry predominately on real phenomena, in classrooms, outdoors, or in laboratory settings, where students are given investigations or guided toward fashioning investigations that are demanding but within their capacities."





Mahoney, Novak, Gleason Greenhills School: NSTA 2006

Essential Features of Classroom Inquiry

- Learner engages in scientifically oriented questions
- Learner gives priority to evidence in responding to questions
- Learner formulates **explanations** from evidence
- Learner connects **explanations** to scientific knowledge
- Learner communicates and justifies **explanations**
- Adapted from the National Science Education Standards

Student Difficulties with Explanations

- Students have difficulty using appropriate evidence and connecting evidence to a claim (McNeill & Krajcik, 2006; Kuhn, 1993; Sandoval & Reiser, 1997).
- Students typically discount data if the data contradicts their current theory (Chinn & Brewer, 2001).
- Most students explanations include claims with little backing (Jimenez-Aleixandre et al., 2000).
- Pre-service teachers' arguments did not include justification (Zembal-Saul et al., 2002).

Explanations in Classroom Practice

- Although important, explanations are frequently left out of classroom practice (Kuhn, 1993; Newton, Driver & Osborne, 1999).

- Few studies have examined the effectiveness of instructional practices in helping students construct explanations (Reznitskaya & Anderson, 2002).

- Project 2061 review of middle school science materials found that most materials were unlikely to result in students developing understandings of key learning goals (Kesidou & Roseman, 2002).

So what's the bottom line….?

- Teachers need support in helping students construct scientific explanations (McNeill & Krajcik, 2006).

A Framework to Construct Scientific Explanation

(from Michigan's IQWST Group)

- Explanation Framework:
  - **Claim**: a conclusion about a problem
  - **Evidence**: scientific data that supports the claim
  - **Reasoning**: a justification that links the claim and evidence together, showing why the data counts as evidence to support the claim by using the appropriate scientific ideas.
- Rule out other explanations

Supports for Explanations

- Making Framework Explicit
  - Purpose of explanation
  - Introduce the framework
    - Reduces complexity
  - Model how to create explanations
    - Everyday examples
    - Discusses strong and weak examples
- Scaffolds for students' explanations
  - Fading supports
- Practice
  - Provide feedback and rewrite

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Using everyday examples to introduce explanations

Explanation Vignette #1

Sally has an awesome shot! She scored 24 points in the game last night. She was 8 for 11 with four three-pointers. She was perfect from the line, making 4 out of 4 free throws. One reason she's so accurate is that she has really good form. She jumps straight up, she extends her arms above her head and she has really good follow through. She also has lots of arch on her shot so if it's not perfect it still has a chance to go in because it can bounce around on the rim and fall through. Another thing Sally has going for her is that she's always really focused. The crowd was so loud last night but Sally wasn't distracted by it. The player that guarded her was also very rough and trashed talked, trying to take Sally away from her game. Sally was still able to focus on her game and really burned her!

- *I predicted that Sally would score 20 points because I've seen her shoot before and knew she had a good shot. I was pretty close even though she ended up scoring even more than I thought!*

Explanation Vignette #2

- These roller blades I bought were really worth the money that I paid for them! ***(Claim)***
- I've had them for a year and logged in over 500 miles and they don't have any scratches. They work as smoothly as the day I bought them. I haven't had to replace anything on them, including the break pads. They're still really comfortable. ***(Evidence)***
- The reason they're so good is that they're made of top quality materials. The wheels are the best made rubber and are attached with the best hardware. The boot is top quality molded plastic with really comfortable cushion inside that just cradles your foot. The material has really lasted - even though I skate almost everyday it still looks and feels like new. The stitching isn't worn at all! ***(Reasoning)***
- I thought (predicted) that these roller blades would last a long time and I'm really happy to say that I was right!

Explanation Vignette #3

- These roller blades I bought are a piece of junk! They were really a poor investment. ***(Claim)***
- I've had them for a year and they're already starting to fall apart. They have scratches all over them. The wheels are rubbing up against the sides of the hardware and it slows me down. The break pads are worn down. The boots are really uncomfortable. ***(Evidence)***
- The reason they're so bad is that the material they're made of isn't the best quality. The wheels are made of plastic rather than rubber. The attachment hardware is plastic instead of steel. The break pads are made of rubber but it's not the best rubber and so it's falling apart from the constant use it gets. The boots are made of molded plastic, which is good, but the inside cushion is wearing out and so my foot doesn't have a good cushion to absorb the force. This results in aching feet! ***(Reasoning)***
- I knew these weren't the best roller blades available but I still predicted that they would be pretty good. I was really wrong. (Prediction)

Critique Explanations

-Circle the ***Claim***

-Number each piece of ***Evidence***

-Underline ***Reasoning***

Rewrite your Explanation

Is there enough oxygen to support aquatic animals in the stream?

Stream Data	Standards	Excellent/Good-
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***Flowing water captures oxygen*
***Organic waste causes oxygen depletion*

Write an explanation that a scientist might write that answers the question, "Is there enough oxygen to support aquatic animals in the stream?"

Is there enough oxygen to support aquatic animals in the stream?

(Jeffrey)

"The dissolved oxygen level is good enough for most aquatic animals and it is in the excellent and good range. Location A is 110%, which is in the excellent range, Location B is 79%, which is in the good range, and location C is 94% which is in the excellent range. This great D.O. level might have happened because of two reasons. Lately, it had been raining a lot and there was a lot of stream flow that could trap lots of air. Second, there weren't a lot of dead organic waste except around location B, where there was a lot of dead cattail. The dead cattail gets decomposed by bacteria, and the bacteria use oxygen, the oxygen then drops….These are great results and it seems that the D.O. level is just right for most aquatic organisms. I hope that they can just keep that high."

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Name:_____

Fall Stream Analysis
Guidelines

All five of the water quality test analyses will follow the format of this guideline sheet.

Label this section, **Fall "…" Analysis**

You have collected data for the stream. You have graphed this data with the standards. You now need to analyze this data.

1. Label this Section Header as "Fall '…' Analysis"

2. Introduce the analysis in one or two sentences.

3. Analyze the data using the information below as a guide. Incorporate all into a complete discussion.

    - Make a **CLAIM** about your results. Decide if the results of your data reflect excellent, good, fair or poor water quality by comparing the results to the standards (ie. "Our results at all three locations suggest that the water quality is fair according to the standards.") If the results are different at each location be sure to address each location.

    - Provide **EVIDENCE** to support your claim. Report your results at each location using the averages (ie. At Location A our average is…., at Location B….) Refer to the graph that you've already created.

    - Discuss **REASONS** why you may have gotten the results. Also discuss reasons that these results are positive or negative (excellent, good, fair or poor) for aquatic life in the stream…both animal and plant.

        - Tie in your background information to help you explain. Look for cause and effect relationships - What may have caused this? What will be the consequences?

        - Look at your physical data and comment about how it may have affected your results. Look for cause and effect relationships (Do you see any physical evidence that could explain your results?)

    - Compare your results with your predictions.

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Water Quality Fall Analysis - WorkSheet

Fill in each box with notes for the test using the **Guideline sheet**. Next, use the notes to write up a complete analysis for that test. Use this format for each test analysis.

Test Analysis Name: Section Header (ie. Fall pH Analysis)	
Introduction	
Make a **CLAIM** about your Results (Excellent? Good? Fair? Poor?)	
Provide **EVIDENCE** to support your claim (Your Data - averages)	
REASONS - explain results 1. Why did you get these results? Explain** 2. Are these results positive Or negative? Explain.** **Use background information and physical data - completely discuss/explain Cause and effect	
Compare your results with your Predictions. Discuss.	
Conclusion. Wrap up the Section.	

Example Explanation

	Properties				
	Color	Hardness	Solubility	Melting Point	Density
Fat	*Off white or Slightly yellow*	*Soft Squishy*	*Water – No* *Oil – Yes*	*47 °C*	*0.92 g/cm^3*
Soap	*Milky white*	*Hard*	*Water – Yes* *Oil – No*	*Higher than 100 °C*	*0.84 g/cm^3*

Write a Scientific Explanation stating whether these are the same or different substances. *(Taken from University of Michigan IQWST Unit: How Do You Make New Stuff From Old Stuff?)*

Scientific Principle

- Substances and properties: Substances are made up of the same type of atom or molecule throughout and can be identified and distinguished by their properties.

Example Scientific Explanations

- Claim = Red Evidence = Blue Reasoning = Purple
- **Explanation #1**
- Fat and soap are both stuff, but they are different substances *(correct claim)*. Fat is used for cooking and soap is used for washing. They are both things we use everyday. The data table is my evidence that they are different substances *(incorrect evidence)*. Stuff can be different substances if you have the right data to show it *(incomplete or vague reasoning)*.

Taken from University of Michigan IQWST Unit: How Do You Make New Stuff From Old Stuff?

Example Scientific Explanations

Explanation #2

- Fat and soap are different substances *(correct claim).* Fat is off white and ivory is milky white. Fat is soft squishy and soap is hard. Fat and soap have different solubility. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. Fat has a melting point of 47° C and soap has a melting point above 100° C. Fat has a density of 0.92 g/cm^3 and soap has a density of 0.84 g/cm^3 *(correct evidence).* Because the color, hardness solubility, melting point, and density are different, I know they are different substances *(correct, but incomplete reasoning).*

Taken from University of Michigan IQWST Unit: How Do You Make New Stuff From Old Stuff?

Example Scientific Explanations

- **Explanation #3**
- Fat and soap are different substances *(correct claim).* Fat is off white and ivory is milky white. Fat is soft squishy and soap is hard. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. Fat has a melting point of 47° C and soap has a melting point above 100° C. Fat has a density of 0.92 g/cm^3 and soap has a density of 0.84 g/cm^3 *(correct evidence).* These are all properties. Because fat and soap have different properties, I know they are different substances. Different substances always have different properties *(correct reasoning).*

Taken from University of Michigan IQWST Unit: How Do You Make New Stuff From Old Stuff?

Student Examples

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Conclusion:

Write a scientific explanation stating whether fat and soap are the same substance or different substances. I believe that soap and fat are not the same substance. This is because all of there properties are different.

I believe fat and soap are not the same substance. (1) Soap is white while fat is transperant. (2) Fat ~~doesn't~~ dissolve in water, soap pracially does. Fat does dissolve in oil, but soap does not. (3) The melting point for the fat was 29.7°c while soaps was over 100°c. (4) Fat is squasy and soft and the soap is ha(5) The density of fat is .92g/cm³ and the density of soap is .84cm³. Sinc soap and fat have very different properties they are not the same

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Conclusion:
Write a **scientific explanation** that states whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.

Claim
(Write a statement that responds to the original problem.)

I believe that the baking soda, powdered sugar, road salt, and phenol red made a new substance.

Evidence
(Provide scientific data to support your claim. You should only use appropriate data and include enough data. Appropriate data is relevant for the problem and allows you to figure out your claim. Remember that not all data is appropriate. Enough data refers to providing the pieces of data necessary to convince someone of your claim.)

This is because all those substances when they were mixed together got fizzy, turned yellow and the bag got filled with air. The bag also got hot and then turned cold. Many of these were properties and when they change the substance does too.

Reasoning
(In your reasoning statement, connect your claim and evidence to show how your data links to your claim. Also, tell why your data count as evidence to support your claim by using scientific principles. Remember reasoning is the process where you apply your science knowledge to solve the problem.)

Therefore I do believe a new substance was formed from the baking soda, powered sugar, road salt, and phenol red. new substance Diff. properties than old substance

(-1)

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Conclusions:

1. Write a **scientific explanation** that answers the question: Does mass stay the same or change when you make gloop?

   (Remember to include claim, evidence, and reasoning.)

2. Look at your prediction at the beginning of the sheet. Did your findings for Conclusion Question 1 support your prediction? Why do you think your findings did or did not support your prediction?

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Data Collection:

After completing each procedure for color, hardness, density, solubility, and melting point, record the properties of your soap in the table below. Then, use the data tables from your previous experiments to fill in the properties for fat.

Object	Properties				
	Color	Hardness	Solubility	Melting Point	Density
My Soap	White	hard	no oil yes water	77.8	1.04 ~~g~~
Fat	off white, ~~translucent~~	very soft	yes oil no water	24.7	92 g/ml

Conclusion:

1. Write a **scientific explanation** that states whether a new substance was formed after mixing the fat and sodium hydroxide solution.

The fat and Soap are two different substances. This is because all the properties for fat and Soap are different. The color of the Soap is White and the color of the fat is ~~off~~ white. The Soap is hard and the fat is very ~~soft~~. Soap is not soluble in oil, fat is. Fat is not soluble in water, Soap is. The melting point for soap is 77.8°c, well fat starts to melt at only 24.7°c. The density of Soap is 1.04g/ml and fat the density of fat is 92g/ml.

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Analysis Header	Sports Drink Analysis
Introduction	People say sports drinks aren't good for you but all the sugar gives you more energy for sports.
Make a **CLAIM** about your Results - include a claim for Each product. Include experi-Ment, taste test and survey	Which sport drink has the most sugar between Gatorade, powerade and vitamin water? If you want a drink for when your playing sports you should drink powerad because it has the most sugar and will give you the most energy.
Provide **EVIDENCE** to support your claim - use graphs you have created.	Powerade has the most sugar and would give you the most energy because it has way more sugar than the others. Then surprisingly to me Vit water has the second most
REASONS - explain results Why did you get these results? Explain using your observations and your data tied with the scientific principles from your background research. Look for Cause and effect Relationships.	• 6 out of 10 people thought powerade has the most sugar the other 4 thought Gatorade • Gatorade has 21.69% sugar residue Vitamin water 13.31% Powerade 21.69% • Gatorade had the most of a rusty orange color it changed color first
Compare your results with your Predictions for each product fro The experiment, taste test and survey	I predicted that Gatorade would have the most sugar so I was right about that but I thought powerde would be second and it was third
Conclusion. Wrap up the Section.	

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Analysis Header	Analysis
Introduction	why Benedicts, why taste. what question is.
Make a **CLAIM** about your Results - include a claim for Each product. Include experi-Ment, taste test and survey	- Benedicts - Red Apple + G Apple most sugar - Tast - grapes = fav + most sugar. - everything else.
Provide **EVIDENCE** to support your claim - use graphs you have created.	explain graphs.
REASONS - explain results Why did you get these results? Explain using your observations and your data tied with the scientific principles from your background research. Look for Cause and effect Relationships.	- In Lemon + grapes tastes most sugar, sugar realeased test, Benedicts proves. - people like grapes + pear best, juicier, sugar realeased. - ~~Even Though~~ even though apples most sugar, takes long to realese sugar proves, so people don't like as much. - Apple very healthy. sugar in fruits good. Apple lots of sugar - ripness - banana's - pear Pretty ripe - book says diff. weighe because of ripness when tested - good sugar, not bad if you eat too much. - fruits healthy expessicaly apple + pear cause most sugar and fruit sugar good.
Compare your results with your Predictions for each product fro The experiment, taste test and survey	look on comp. and compaine
Conclusion. Wrap up the Section.	- ~~All~~ even though Apple most sugar, not popul or not detrotable - grape not a lot of sugar, most pop. and thought most sugar. - why did the questions we did Answer ?s on

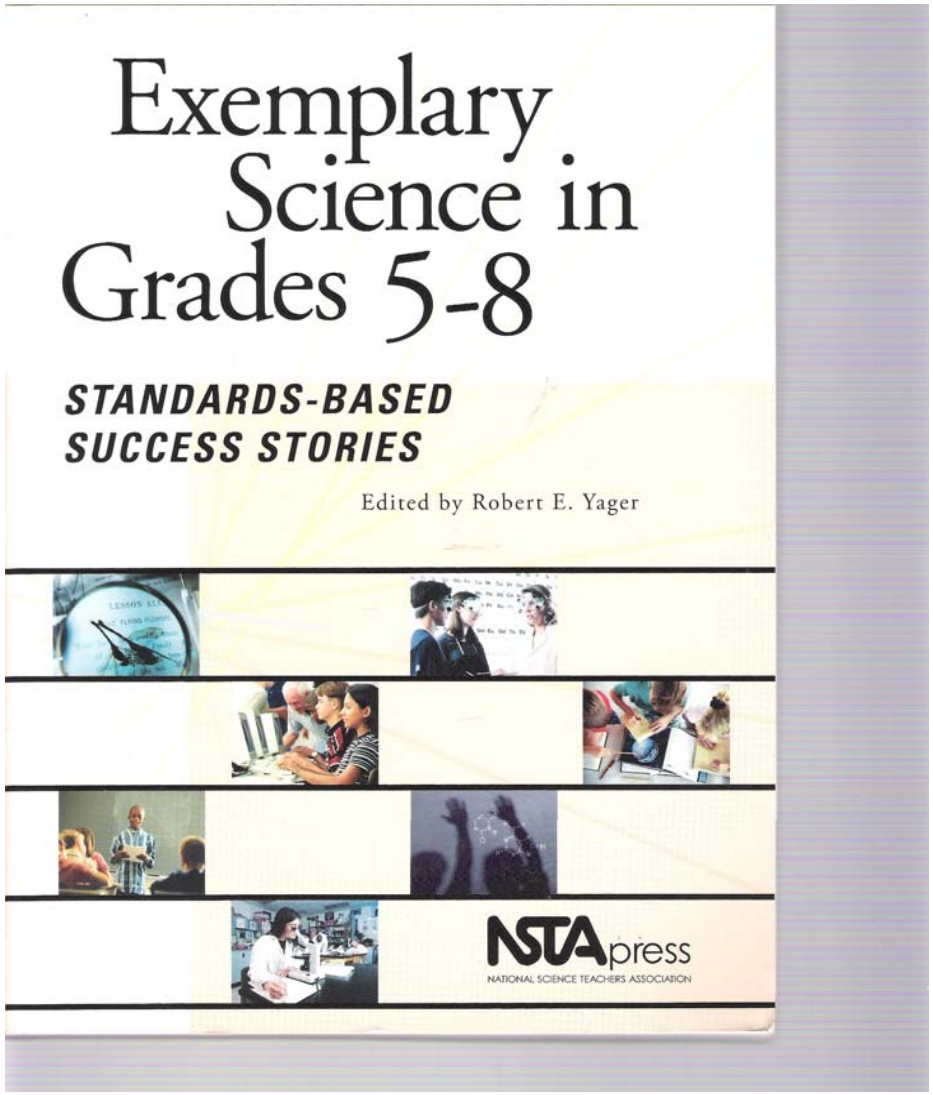
Miranda's Analysis

- Our Question is: "What fruit, out of the ones we tested, has the most sugar?" In our results for the Benedict's test the red apple had the most sugar, the green apple had the second most, the pear next, then grapes and last was the lemon. Most people said that their favorite fruit was grapes, second most, pear, then lemon and green apple were tied, with the last being the red apple. The fruit that tasted like it had the most sugar was grapes, second was lemon and lemon was third.
  In my graph from the taste test results it shows what fruit people thought had the most sugar and what fruit was people's favorite. Eight people thought that grapes had the most sugar and five people said it was their favorite. Five people said that the lemon had the most sugar and three of them said it was their favorite. Three people thought pear had the most sugar and four people thought it was their favorite. No people thought either of the apples was the sweetest and one person thought that the red apple was their favorite.
- I wanted to find out if the amount of sugar fruit influenced peoples choice of favorite fruit. This turned out to be false, red apple had the most sugar and only one person said it was their favorite. I also wanted to find out if the amount of sugar was detectable in fruits. This also turned out to be false, because people thought that grapes tasted like they had the most sugar although apples had the most. Neither lemon or pear had the most sugar and people thought that it did. This could be because the sugar in those fruits are released fast and it is easier to taste. Our benedicts test proves that the sugar is released fast because they were among the fruits with the Benedicts test that changed the fastest.
- We think people like the grapes and pears the best because they are both juicy and sugar is tasted easily. Even thought apples had the most sugar they are tough and not very juicy. During our Benedicts test the apples took the longest time to change color, proving that sugar doesn't get released fast. This is why people do not rank them as very sweet. We received different results then a book said we would. This could be due to the ripeness of the fruit we tested. We did an experiment with bananas and we found out that the amount of sugar increases as fruit ripens. This could explain the results we got that pears have more sugar than grapes and the book we read said that grapes have more. It could have been the pear was riper than the grapes we used. We found that the apple had the most sugar and the reason everyone believes that it is healthy is because it is natural sugar and is filled with vitamins, minerals and fiber. This means that you can enjoy eating as many fruits as possible it is healthy for you even if they are sweet.
- My predictions did not match our results except when I predicted that people would think that the grapes tasted like it has the most sugar and they did because it is easier to taste the sugar in grapes due to their smallness and quick release of sugar. Overall our experiment was successful and our question was answered.

Supporting Students in Creating Explanations

- **Make the framework explicit**
- **Model the construction of explanations**
- **Provide Feedback**
- **Allow students to critique explanations**
- **Practice**

Shameless Plug…



Check out Chapter 6:
Creating a Classroom Culture of Scientific Principles

Conclusion

- Explanations can help students learn
- But you need to
  - Provide explicit directions
  - Give feedback
  - Allow for students to write, critique and revise their explanation

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