Spark Curiosity, Fuel Scientific Inquiry: Teach students to ask their own questions

Katy Connolly The Right Question Institute

Rachel Riemer Buckingham Browne & Nichols School



rightquestion.org

Who is in the room?

To Access Today's Materials:

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Classroom Examples

Instructional Videos

Planning Tools & Templates

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Today's Agenda

1) Welcome

- 2) Why Spend Time on Teaching the Skill of Question Formulation?
- 3) Collaborative Learning with the Question Formulation Technique (QFT)
- 4) Explore Real Classroom Examples & Applications
- 5) Why is Question Formulation Important Now?
- 6) Final Thoughts & Reflection





Why spend time teaching the skill of question formulation?

Origin of the Right Question Institute: Parents in Lawrence, Massachusetts, 1990



"We don't go to the school because we don't even know what to ask."

"There is no learning without having to pose a question."

- Richard Feynman

Nobel Laureate, Physics, 1965



"We must teach students how to think in questions, how to manage ignorance."

– Stuart Firestein

Former chair, Department of Biology,

Columbia University

College Presidents on What College Students Should Learn

"The primary skills should be analytical skills of interpretation and inquiry. In other words, know how to frame a question."

- Leon Botstein, President of Bard College

"...the best we can do for students is have them ask the right questions."

- Nancy Cantor, Former Chancellor of University of Illinois

The New York Times, August 4, 2002

Yet, Only 27% of Graduates Believe College Taught Them How to Ask Their Own Questions

<u>**</u>*** ************************

📄 Agree 🔵 Disagree

But, the problem begins long before college...

Question Asking Declines with Age



Which students ask questions?

BY HIGH SCHOOL, HIGH ACHIEVING STUDENTS WERE ASKING ON AVERAGE



MORE QUESTIONS IN A CLASS PERIOD THAN THEIR MIDDLE AND LOW ACHIEVING PEERS

MALE STUDENTS ARE



MORE LIKELY TO ASK A QUESTION IN AN ACADEMIC SEMINAR

We can work together on creating more opportunities for all students to ask their own questions

We Are Not Alone More than 1 million classrooms worldwide



MAKE JUST ONE CHANGE

> Teach Students to Ask Their Own Questions

DAN ROTHSTEIN and LUZ SANTANA Foreword by WENDY D. PURIEFOY





What happens when students do learn to ask their own questions?

Research Confirms the Importance of Questioning

Self-questioning (metacognitive strategy):

- Student formulation of their own questions is one of the most effective metacognitive strategies
- Engaging in pre-lesson self-questioning improved students rate of learning by nearly 50% (Hattie, p.193)

John Hattie

Visible Learning: A Synthesis of Over 800 meta-Analyses Relating to Achievement, 2008

Student Reflection



"The way it made me feel was smart because I was asking good questions and giving good answers." -Boston 9th grade summer school student





Collaborative Learning with the Question Formulation Technique (QFT)

There are 2 icons you will see:



Please think or work on the task assigned



Use the chat box to share some of your work

The Question Formulation Technique (QFT)

Individuals learn to:

- Produce their own questions
- Improve their questions
- •Strategize on how to use their questions
- Reflect on what they have learned and how they learned it



- 1. Ask as many questions as you can
- 2. Do not stop to answer, judge, or discuss
- 3. Write down every question exactly as stated
- 4. Change any statements into questions

Produce Questions

- 1. Ask Questions
- 2. Follow the Rules
 - •Ask as many questions as you can.
 - •Do not stop to answer, judge, or discuss.
 - •Write down every question exactly as it was stated.
 - •Change any statements into questions.
- 3. Number the Questions





Some students are not asking questions.

□Now, ask questions. Number the questions. Follow the rules:

Ask as many questions as you can. Don't stop to answer, judge, or discuss. Record each question exactly as it was stated (or first came to mind). Change any statements into questions.

Categorize Questions: Closed/Open

Definitions:

- •Closed-ended questions can be answered with a "yes" or "no" or with a **one-word** answer.
- •**Open-ended** questions require more **explanation**.

<u>Directions</u>: Identify your questions as closed-ended or open-ended by **marking them** with a "**C**" or an "**O**."





Closed-ended Questions

Advantages





Open-ended Questions

Advantages



•Take one **closed-ended question** and change it into an **open-ended question**.



•Take one **open-ended question** and change it into a **closed-ended question**.

• Add these as new questions to your list

Prioritize Questions

Review your list of questions

- Choose three questions that you feel are most important.
- While prioritizing, think about your Question Focus, Some students are not asking questions.
- •Then, think about why you chose those questions.

Share using Padlet

https://padlet.com/katyconnolly1/6gb5oqtwtx9dxqpx

A Look Inside the Process



The QFT, on one slide...

- 1) Question Focus
- 2) Produce Your Questions
 - \checkmark Follow the rules
 - ✓ Number your questions
- 3) Improve Your Questions
 - ✓ Categorize questions as Closed or Open-ended
 - ✓ Change questions from one type to another

4) Strategize

- ✔ Prioritize your questions
- ✓ Action plan or discuss next steps
- ✓ Share
- 5) Reflect

- 1. Ask as many questions as you can
- Do not stop to discuss, judge or answer
- 3. Record exactly as stated
- 4. Change statements into questions

Closed-Ended: Answered with "yes," "no"

or one word

Open-Ended: Require longer explanation

<u>Three</u> thinking abilities with <u>one</u> process

Thinking in many different directions


Narrowing Down, Focusing



Thinking about Thinking



Metacognition





Exploring Classroom Examples

+

Classroom Example: High School Physics

Teacher: Rachel Riemer, Cambridge, MA

<u>Topic:</u> Relationship between angle of incline and acceleration

<u>Purpose:</u> For students to develop their own question to investigate in a lab

Question Focus





Motion on an incline

Student Questions

Motion on an Incline -Is there uniform acceleration? Closed -Is there uniform acceleration? Closed -Are use measuring a specific incline? Closed -Are you going up or down? Closed -Did Isaac Newton discover the equation for it? Closed -Did Isaac Newton discover the equation for it? Closed -Does weight matter for the motion? Closed/Open -Is there a starting velocity? Closed -Is gravity involved? Closed -Is gravity involved? Closed

*-How long are you traveling for on the incline? Closed -Does the shape of the object affect motion? Closed lopen +-How much friction is there? closed -Can the topoles be put on an incline? closed -Does the angle affect the acceleration exponentially? closed -Does the angle affect the acceleration exponentially? closed -Ts there any other form of resistance (besides possibly friction)? closed/open -How would a non-uniform incline be represented on a velocity graph? open -How would a non-uniform incline be represented on a velocity graph? open -Con you use the same equations? (losed/open

Next Steps with Student Questions

Original Questions

These questions were generated using the QRT method, a method of generating as many questions as possible in order to spark curiosity about a particular topic.

- Is there uniform acceleration? (closed)
- Are we measuring a specific incline? (closed)
- Are you going up or down? (closed)
- Did Isaac Newton discover the equations for it? (closed)
- Does weight matter for the motion? (closed/open)
- Is there a starting velocity? (closed)
- Is gravity involved? (closed)
- 8. How long are you traveling for on the incline? (closed)
- 9. Does the shape of the object affect motion?(closed/open)
- 10. How much friction is there? (closed)
- 11. Can the tracks be put on an incline? (closed)
- Does the angle affect the acceleration exponentially? (closed)
- Is there any other form of resistance (besides possibly friction)? (closed/open)
- 14. How would a no-uniform incline be represented on a velocity graph? (open)
- Can you use the same equations? (closed/open)
- What effect would air resistance have on the motion? (open)
- 17. How much energy is required to move up an incline? (closed)
- Is there a maximum speed you can reach when going down an incline? (closed)
- Is there a minimum speed you can reach when going up an incline? (closed)
- 20. Does weight change the coefficient of acceleration up an incline/down an incline/ on an incline? (closed/open)

Our group settled on the question: Does the angle affect the acceleration exponentially?

| vey: |
|-----------------------------------|
| Closed Question |
| Yes/No Question |
| Questions that we changed to open |
| Open Question |
| This/The |
| Question With Numerical Answer |

We thought these categories most accurately described our data because we had a lot more closed questions, and in order to avoid simply having two categories, we delved more into the possible answers to the questions. We found categorizing types of closed questions helped us think about how we might solve the question.

Next Steps with Student Questions



Does the angle of the incline affect the acceleration exponentially?



What would the velocity and position graphs of an object moving up and down an incline look like?

Students Improve and Add Questions

Altering The Question Based On Our Experiment:

While initially all agreeing on the question, we did not have the same understanding of what exponential meant. As a result, solving this question naturally morphed into a simpler question: What is the relationship between incline angle and acceleration?



Outcome:

we weren't able to see what that relationship might be. As a result, while generating our second set of questions, we decided to settle on the question of "do multiple lines appear to satisfy the points?" In an effort to answer this question, we thought that more data points would be helpful, so for our next course of action, we collected more points.

Comfort in the Unknown

"In the end, It is evident that none of our graphs were the perfect fits for our data. It is obvious that the linear fit didn't work, and while the quadratic line of best fit appeared to fit the most appropriately, it still wasn't perfect. We came to the conclusion that no function in our toolkit would be the perfect one." equal to .1 m/s



Enduring Questions

- 1. Would require more testing/ new trials:
 - a. If we added a drastic amount of mass would we be able to see a difference?
 - b. Could weight factor into an equation for motion on an incline?
 - c. How might the distribution of weight on the cart affect its motion?
 - i. 2 weights neg direction: m (Slope): 2.126 m/s²
 - ii. 2 weights pos direction: m (Slope): 2.119 m/s²
 - iii. 2 weights diagonal: m (Slope): 2.100 m/s²
- 2. Graphing/representational:
 - a. Why is the correlation always 100% for quadratic LOBFs on the position graphs and a couple ten-thousandths short of 100% for linear LOBFs on the velocity graphs?
 - b. Does the +/- (some value) included in A, B and C for the LOBFs of position graphs represent error bars (the true values of A, B, and C could be anywhere within that range)? If so, why is the range of error/ the value after +/- sign different for each trial?

Student Reflections

What did you learn today?

"I learned that sometimes the questions which seem the most simple are the best ones to ask because they ground you in the fundamental understanding of the topic- at first I was sort of trying to come up with complicated or specific questions but the QFT today taught me to think in a more broad/discussion-starting/open-ended way rather than trying to address a small, detailed and closed area of the topic."

Student Reflections

How did you feel as you went through the QFT today?

"I really enjoyed the QFT today. More often than not, I tend to spend class time simply listening to lectures rather than proclaiming what it is that I actually want to know. Being able to change things up today was certainly fun. I had two very good groupmates who consistently brought up thoughtful questions while keeping the discussion interesting; they definitely had some ideas that I would have otherwise never come across."

Student Reflections

How did your thinking change as you asked questions?

"As I asked more questions, I began to think more broadly and didn't just focus on velocity or acceleration. I also wondered about gravity and energy." Classroom Example: High School Chemistry

<u>Teacher:</u> Sara Stephenson

<u>Topic:</u> Physical and chemical properties and changes

<u>Purpose:</u> For students to plan and perform an investigation to test/answer one of their priority questions

Question Focus



Student Questions

- 1. What are the substances?
- 2. Why does it change colour?
- 3. What can we do to determine what the substances are?
- 4. How did the clear liquid affect the chemical change?
- 5. Does there need to be a specific measurement of the liquid and powder to ignite?

6. Does it change colour because it's heated?

7. What causes the flame to go out?

8. Are the substances in the watch glass flammable?

9. How much liquid was in the beaker?

10. Does the colour of the solid impact the flame colour?

Students' Priority Questions

- 1. What are the substances?
- 2. What was the rope being soaked in?
- 3. Is there a chemical change occuring?
- 4. Why does it change colour?
- 5. Was the clear liquid flammable or was it the substances in the watch glass?
- 6. What can we do to determine what the substances are?
- 7. What causes the different colours?
- 8. How did the clear liquid affect the chemical change?
- 9. How much of each substance was used?
- 10. Why does it become a coloured flame and not a regular flame?
- 11. Does there need to be a specific measurement of the liquid and powder to ignite?
- 12. Does it change colour because it's heated?

Next Steps with Student Questions

• Students prioritized questions based on actions they wanted to take

Examples: the 3 most important questions at this time, 3 questions you would like to address first, 3 questions you want to explore further

• In groups, students determined which of their priority questions were testable questions or re-writing to turn into testable questions

Definition of testable questions: they are always about changing one thing to see what the effect is on another thing. We have to be able to perform an experiment to determine if it's true or false.

Priority → Testable Questions

- Does changing the amount of liquid affect the size of the flame?
- How does changing the substance affect the colour of the flame?
- If the rope is changed, will it affect the flame colour/size?
- Does changing the room temperature affect the flame size/colour?
- If we were to change one solid, would it affect the flame height?
- Does changing how much liquid was used effect how long the experiment lasted?

Next Steps with Student Questions

After picking one of their testable questions, student groups designed an experiment to test it

<u>Purpose:</u> Why are you doing this experiment? What are you trying to find out (To determine if the colour of the solid impacts the flame colour of the substance)

<u>Hypothesis:</u> If the colour of the solid is compared to to the flame colour, then ...

Materials:

- Compounds listed in observations
- Hydrochloric acid
- Nicrome Wire
- Bunsen Burner
- Flint Lighter

Observations:

Table 1: what is in your table?Comparison of solid colour, experimental flame colour and theoreticalflame colour for various ionic compounds.

| Color of solid | Experimental Flame colour | Theoretical flame colour |
|----------------|------------------------------|--|
| | | |
| | | |
| | | |
| | Color of solid | Color of solid Experimental Flame colour |

Classroom Example: High School Environmental Science

<u>Teacher:</u> Sara Stephenson, Ontario, Canada

<u>Topic:</u> Climate change

<u>Purpose:</u> To generate questions of interest for a mini research project

Question Focus

River 1, position 16, altitude 707 m, Greenland ice cap melting area],



Student Questions

- 1. How cold is the water?
- 2. Is there any animals there? or people?
- 3. Why did the water melt in a cold area?
- 4. How might global warming affect the glacier?
- 5. How warm/cold is it?
- 6. Why didn't the snow melt with the water?
- 7. How much has the temperature changed?
- 8. Why is there snow if the ice is melting?
- 9. Is the ice melting?
- 10. How fast does the ice melt?
- 11. Is the change in temperature the cause of the ice melting?
- 12. How long does the water go for?
- 13. Is this natural?
- 14. Where was this picture taken?
- 15. Is the water getting deeper?
- 16. Or does it drain somewhere?

18. What is the black stuff?

- 19. How dense is the atmosphere there?
- 20. Did it always look like this?
- 21. How long does it take to melt?
- 23. What time of year is this?
- 24. Is it ever sunny out?
- 25. How thick is the glacier?
- 26. Does it get thinner when it melts?
- 27. Is the environment dying?
- 28. What is the average temperature for each month?
- 29. Where does the water lead to?
- 30. How fast is it melting?
- 31. Is the ice melting?
- 32. What is under the ice?
- 33. How does ice melting affect humans?

Next Steps with Student Questions

How Might Global Warming Affect The Glacier?

As the Earth warms, the melt line moves upwards so that the glacier melts faster and faster at the bottom, shortening the glacier and reducing its mass. Ultimately, the melted water flows into streams and rivers and ends up in the oceans, contributing to accelerating sea level rise.



Students did
 internet research to
 answer a priority
 question and share
 in a class slide
 deck.

 Students created short 3-5 minute informative videos climate change & human health.

High School Biology

Teacher: Dr. Leah Cataldo Cambridge, MA

7 Properties of Life









Regulation: Jackrabbit



Energy Processing: Butterfly on flowers



Evolution and

Growth and

Development:

Oak Seedling

Response to the







- 1. Ask as many questions as you can
- 2. Do not stop to discuss, judge or answer
- 3. Record exactly as stated
- 4. Change statements into questions

There are seven properties that are associated with something being characterized as living.

Observe this figure that names each of the seven properties together with an *image that portrays* that attribute in living things.

Working with your partner over the next three minutes, write down as many questions as you can that come to mind based on those names and images.

Choose three questions that...

You can use the internet to explore. Bring what you learn to our next class (brief summary/bulleted list).

AP Biology

Teacher: Dr. Leah Cataldo Cambridge, MA

Introduction to Water Potential

Net water potential depends on the effects of both solute concentration Ψ_{π} and pressure Ψ_{p} .



- 1. Ask as many questions as you can
- Do not stop to discuss, judge or answer
- 3. Record exactly as stated
- 4. Change statements into questions

2021 Questions

- What is the relationship between [solute] and pressure?
- What is a scenario where osmotic potential is (-) and pressure potential is (-) but rising? ***
- · Why does concentration always have a (-) vector
 - Because adding solute lowers water potential
- · What is the water potential of pure water?
 - Zero, answered in the graph presented
- Does net water potential differ with different environmental conditions?
 - How does a change in ____ influence net water potential?***
- How do cells adapt to changes in water potential?

Classroom Example: AP Physics

- Teacher: Rachel Riemer, Cambridge, MA
- <u>Topic:</u> Bias in science

<u>Purpose:</u> To open up discussion around an important issue

Question Focus: Bias in Science

Philip Live Bias in Science EWhat is bias in science? Who is bias? OHow much does bios affect science? OWhen is bias?" E What is science ? E What is bias ? [Where is bias?" E. Is there always bias in science? Otlov is bian? E Where loes bias come from?" (Why is bias?) E How do you prevent bios ? Does biss influence science, OCan you prevent bias? or is it a port of it? OWhat role does bias have in science?" E Should we core about bios in science? When? E Are scientists biased?" OCan bias be helpful in science? O Can bias be hormful in science ?" O Can we measure bias? E Would the world change if there has no bias? Ottow much bios is in an average science? Obblot discipline of science has the most bias?" Other would the world change it there was no bias?"-OIs biss in the experimentation, or the presentation of result?" Els bias human error ?-> OAre humans responsible for their bias ?

Michael Kenijan W

Vtj Bias in Science Why would What is bias in science! O you bias What counts as bias of what is When does bias occur Acousts as Is all science biased. Obias? to wards things . What types of things would hold biases about and my What isn't bias? 0 · Why are people biasel · And why are people not brased ? O . How do highschoolers stop bias () How do scientists use bias · Is anything no thiasel 6 What isn't biased in science () · Can bias ever be eximinated @ · whattypes of science tare the most bias? C Climate change is a thing? O Man you write vinayak next to that? C . How long have we done bias? O How long have we been brased !! . How do we reduce bias? () What next? C · Do people working in crime forensis labs raise bias? . What types of ethical difenmas does that mise? O How do we relate this to alab ?? · To overlas? when does that mean? C . Is there bras in the scient i'fi'c method? A new eusing bias right now? O Is bias gool? O what is buo about bins? C ·canbias be good! when!

Bias in Science C=closed 0=open ** 0 = How are scientists affected by bias O = What is bias 0 - how do Scientist's biases affect Lablexperiment results 0 - how often is bias represented in resultr O = how do we design experiments to be bias free O how can we dublee 050 our expirements with higs in mind o/c =are all scientists affected by bias 0 - What recent scientific discoveries have been informed by bigs olc = is scientific bias dangerous O = What gre scientists biased by * C = are numbers subjected to bigs 0 = what specific part of an experiment is most easily influenced by bias o mat which stage in the scientific method is bigs most in fluen tial O = What can de to prevent bias in future O = which occus more: experiments affected by blas or appelments designed that based on bras * 0 - what effects can bias have on numbers and exportmental data * c - what is an example of an instance where scientists were affected by bias · Eliminating bias · Causes of bigs · Effects of bigs Nature of his

Student Questions

- What are some occurrences? 1.
- What topics in science have most bias? 2.

How is bias defined? 3.

- Are there different types of biases in 4. science?
- How does bias affect experiments and 5. results?
- How does bias influence data 6. collection?
- Is it possible to be completely bias free? 1.
- How to reduce bias? 8.
- 9. Why is there bias?
- Is bias intrinsic? 10.
- 11. 12.
- Is bias necessarily bad? How important is the fact that there is bias? (O)

13. Is it important that there is bias? (C)

14. When in history did bias in results of experiments affect the public?

15. How do you quantify bias?

- 16. What increases/decreases bias?
- 17. What is the trend of bias in science? More? Less?
- 18. Are certain groups of people more easily biased? (C)
- 19. What are the certain groups of people? (O)
- 20. How can we eliminate bias in high school experiments w/o high tech?
- 21. What's in place now to reduce bias?

Next Steps with Students Questions

- Students identified patterns that emerged from their questions
- They categorized their questions into those patterns
- Students' priority questions were used as a class discussion activity

- buckgrown Prompt: Blas in Science History Elwhoe are some ocurrences? delinitio Elwhat topics in science have most bias? () Erlaw is bias defined? >> 0 14- examples IPR there diff types of biases in science? C How does beas affect results? M-impact Capenments + help/reduce MI-patterns/trends influence acta collection 0 Is it possible 26 completely bias-free? Dic Etlows reduce beas? O Elwhy is there bias? O Els bias intrinsic? C Els bias nucessanly bad? C E How important is the fact that there is blas? () I the important that there is brass? C when in mistory did blas in experiments affect \$ Public? 0 results of E How quantify blas? () Divinue in creases/decreases 61as? 0 = What is the trend of bias in some ? More? less DAre certain groups of pp1 more easily brased? What are the certain groups of pp1...? O

Conta Ettaw can we eliminate bias in high school experiments who histern? Elwhats in place now 2 reduce blas? () Our 3 ?s and why they're important/why we're interested - How is bias defined 4 fundemental question 4> Dictates how we interpret further exploration - History result experiment affect public 4 We could be living in a skewed world 17 did it affect pp1 disproportionally 47 does it create distrust blw public and science work - Diff groups of people - bias

History/definition

- How is bias defined?
- Why is there bias?
- Is bias intrinsic?
- Is bias necessarily bad?
- When in history did bias in results of experiments affect the public?
- How do you quantify bias?

Examples

- What are some occurrences?
- What topics in science have most bias?
- Are there different types of bias in science?

Impact

- How does bias affect experiments and results?
- How does bias affect influence data collection?

Help/reduce

- Is it possible to be completely bias free?
- How do you reduce bias?
- What increases/decreases bias?
- How can we eliminate bias in high school experiments w/o high tech?
- What's in place now to reduce bias?

Patterns/trends

- What is the trend of bias in science? More? Less?
- Are certain groups of people more easily biased? (C)
- What are the certain groups of people? (O)

Continue to add ideas to the Padlet

How could you use the QFT in your work?

https://padlet.com/katyconnolly1/6gb5oqtwtx9dxqpx

Why is the skill of question formulation so important now?

In the Age of Google



"How should you respond when you get powerful new tools for finding answers?

Think of harder questions."

– Clive Thompson Journalist and Technology Blogger

Questions and Democracy



"We need to be taught to study rather than to believe, to **inquire** rather than to affirm."

– Septima Clark

Chapter 6 on Septima Clark in Freedom Road: Adult Education of African Americans (Peterson, 1996)

Final Reflection

https://bit.ly/QFTKeynoteEval
Thank you!



rightquestion.org

Classroom Example: High School Physics

Teacher: Rachel Riemer, Cambridge, MA

<u>Topic:</u> Relationship between angle of incline and acceleration

<u>Purpose:</u> For students to develop their own question to investigate in a lab

Question Focus





Motion on an incline

Student Questions

- forces "Motion on an Incline" -graphs -incline -What does the position graph look like? Open (0) = - How does the a vary of an object going up an incline vs. down an incline? O - Dues there have to be a minimal speed in order for an object to travel up an incline? C= -Is moving up on incline like changing direction? Com -Dues going up or down an incline affect the amount of time it takes if or an object to reach a valueity of 07. C= - How on incline affects an object already moving in a constant =? ? - How much more energy would it take to more up? C . -Does the surface of the incline affect the rate of a? ? Can -Until what slope does it become almost impossible to move at an incline? Co - Could your speed up to get up on indine without changing volacity? Co - Are horizontal or vertical lines considered inclines? C - What's the difference between vehicity while going up an incline are down the same slope? Omm - How would you show the motion of going up with a lot diagram? On -Dues the amount of air resistance change going up or down on incline ? Com - What happens when the stope of an incline slowly changes? - How would you show on a position graph in the object rolls backward? -Is there ever a time on an incline when an object has negative potential energy? Com -What if an object stops on an incline? O -Is the velocity of an object different if it's going horizontally across an incline rather than a flat surface? (- Does the intensity of the force of gravity affect the acceleration? C - Does the location of the incline affect the velocity? C . - When going up a slope, is there a mail weight for an object to get up it? (- How far does an object have to fall to reach a max speed? C - Can an objectorer reach a max velocity on an Incline ? Co - what shape is the most acrodynamic when going on an Indine ? . - If an object bources up or down on an incline, which do the position and velocity graphs look like? - Does it take an abject more cheave to maintain a consistant udecity upidown incline rather than on a

Motion on an Incline -Is there uniform acceleration? Closed = yes/no = = with explanation = this/that ** - Are we measuring a specific incline? Closed =numerical * - Are you going up or down? Closed =open "-Did I saac Newton discover the equation for it? Closece 1+ - Does weight matter for the motion? closed lopen **-Is there a starting velocity? Closed -Is gravity involved? Closed *- How long are you traveling for on the incline? Closed **-Does the shape of the object affect motion? Closedlopen *- How much friction is there? Closed **- Can the topoles be put on an incline? closed -Does the angle affect the acceleration exponentially? closed Is there any other form of resistance (besides possibly friction)? closed/open #-How would a non-writting incline be represented on a velocity graph? OP - Can you use the same equations? Closed lopen t-What effect would air resistance have on the motion? Open #- How much energy is required to move up an incline? Closed "Is there a maximum speed you can reach when going down an incline? Close "Is there a minimum speed "when going "Closed Does weight change the coefficient of acceleration sup an incline/down an incline an incline closedlopen

would the acceleration increase constantly if something was

going down an incline?

Would the motion of an object on an include look different than an object gang up in position (is; jumping) without samething understand Would it require more energy for an object to maintain the same velocity when traveling on an include?

Why is the prompt in guotation marks? does incline have to be a physical incline?

Does the weight of an object have a big impact on the motion down an incline?

How much does air resistance affect an object moving on an incline that doesn't leave the grown

Do Different forces affect motion on an incline, compared to not on an incline ?

Is there a way to predict the velocity of an object on an incline before experimenting?

Is motion on an incline any different than motion not on an incline in space/zero gravity? How does earth's atmosphere affect incline motion?

Are there different equations for motion on an incline?

Can two objects have different accelerations if they more on the same incline

Is there any incline that goes on Porever (if object isn't physically stopped will just keep going How much energy is required for an object to go down an incline woo any outside help (Battery)?

How does the surface of the track impact the acceleration?

Does it take more of less force for an object on an incline to an incline to an incline to an

How would you represent motion on incline on position graph?

Would the displacement of the object still be rep. by the entire area under the line on the gi or just a port?

Would Friction make more of a difference for an object on an heline?

Next Steps with Student Questions

- Students categorized their questions into topics using color-coding
- Within those categories, students' identified a "lead question" and the questions they'd have to answer first to get at the lead question
- Students prioritized with the instructions, "If you were to design a lab, which question would you design a lab around, and why?"
- Students then designed a lab to answer their question.



Next Steps with Student Questions

- Most groups ended up choosing very similar questions, either: How does the mass of the cart affect the motion? Or how does the angle of incline affect the motion?
- Partner groups identified dependent variable(s), independent variable(s), and the set up for their experiment, all groups using the same materials.
- Over the course of the next few days, they experimented and collected data.
- They gathered their initial questions, thought process in designing a lab, and results in a final Powerpoint presentation that they each presented to the class.



Does the angle of the incline affect the acceleration exponentially?



What would the velocity and position graphs of an object moving up and down an incline look like?

Students Improve and Add Questions

Altering The Question Based On Our Experiment:

While initially all agreeing on the question, we did not have the same understanding of what exponential meant. As a result, solving this question naturally morphed into a simpler question: What is the relationship between incline angle and acceleration?





Outcome:

After collecting four data points and graphing their accelerations, our group concluded that there is definitely a relationship between the angle of the incline and the acceleration of the object. However, with our four data points, we weren't able to see what that relationship might be. As a result, while generating our second set of questions, we decided to settle on the question of "do multiple lines appear to satisfy the points?" In an effort to answer this question, we thought that more data points would be helpful, so for our next course of action, we collected more points.

Comfort in the Unknown

"In the end, It is evident that none of our graphs were the perfect fits for our data. It is obvious that the linear fit didn't work, and while the quadratic line of best fit appeared to fit the most appropriately, it still wasn't perfect. We came to the conclusion that no function in our toolkit would be the perfect one." equal to .1 m/s



Enduring Questions

- 1. Would require more testing/ new trials:
 - a. If we added a drastic amount of mass would we be able to see a difference?
 - b. Could weight factor into an equation for motion on an incline?
 - c. How might the distribution of weight on the cart affect its motion?
 - i. 2 weights neg direction: m (Slope): 2.126 m/s²
 - ii. 2 weights pos direction: m (Slope): 2.119 m/s²
 - iii. 2 weights diagonal: m (Slope): 2.100 m/s²
- 2. Graphing/representational:
 - a. Why is the correlation always 100% for quadratic LOBFs on the position graphs and a couple ten-thousandths short of 100% for linear LOBFs on the velocity graphs?
 - b. Does the +/- (some value) included in A, B and C for the LOBFs of position graphs represent error bars (the true values of A, B, and C could be anywhere within that range)? If so, why is the range of error/ the value after +/- sign different for each trial?

Student Reflections

| What did you learn today? | How did you feel as you went through the QFT today? | How did your thinking change as you asked questions? |
|---|--|---|
| I learned that asking multiple questions, even if they don't seem related, can lead to other interesting questions. It can also seem like you don't have any more questions, but if you just think, there are actually a lot more. I also realized that in each group we came up with similar questions. | I felt like at first we had more questions as a group, but then we began to be more specific/creative as the big questions were said. Though it was sometimes hard to come up with a question, the QFT definitely made you think harder about motion on an incline than just learning about it. | As I asked more questions, I began to think more broadly and didn't just focus on velocity or acceleration. I also wondered about gravity and energy. |
| I learned that sometimes the questions which seem the most simple are the best ones to ask because they ground you in the fundamental understanding of the topic- at first I was sort of trying to come up with complicated or specific questions but the QFT today taught me to think in a more broad/discussion-starting/open-ended way rather than trying to address a small, detailed and closed area of the topic. | I initially felt like I was asking the wrong types of questions - it seemed like Ms. Riemer was looking for something other than what we were saying, and I thought I was going to run out of questions, but by the end I think everyone became a little more comfortable because people started spouting questions and I was surprised how we were able to continue generating so many ideas. | My thinking kind of expanded in relation to my approach to the prompt; I initially went from considering how velocity and acceleration might change under specific circumstances to how they might interact in general, how they might be written, graphed, etc. |
| Today I learned how easy it is to generate questions when you simply let your mind wander. However, I also found myself asking questions that I know the answer to, which isn't always productive. | I felt a little agitated when people asked questions that seemed pretty obvious and I felt they should've known the answer to, but reflecting on that feeling, it is all part of the process. | At the start I was focused on asking "good questions," but as I let my mind wander, I let myself ask any question that came to my head, which I think is part of the process. |
| Today, I learned about some new factors that affect motion. While discussing movement on an incline with my classmates, we came across many different ideas. For example, the concepts of mass, speed, and slope were spoken about often. I learned a lot throughout the questioning process. Subjects like air trajectory, gravity, and friction broadened my initial thoughts. I even began to picture new types of graphs and their possible equations. | I really enjoyed the QFT today. More often than not, I tend to spend class time simply listening to lectures rather than proclaiming what it is that I actually want to know. Being able to change things up today was certainly fun. I had two very good groupmates who consistently brought up thoughtful questions while keeping the discussion interesting; they definitely had some ideas that I would have otherwise never come across. | Initially, many of my questions seemed to coincide with ideas about acceleration and velocity. But, as the conversation went on, I started to wonder more about the physical make-up of the graphs (displaying an object traveling up an incline). Not to mention, I started to question how various factors (beyond velocity and acceleration) would affect motion on an incline. Getting to talk with other people and look at the work of other groups definitely helped to change my thoughts around. |

Teacher Reflections

"At first, they weren't buying in. They would say, 'Just tell us what you want us to do.' It took them awhile to trust each other too. Now, most of the students will say they really like the flexibility in the labs, that because not everyone is doing the same thing they learn more, and being in the lab is their favorite part."

For quiet groups:

- "Give them time to sit quietly, come up with their own questions individually, then go around in a group and record, and give some time to keep adding questions as a group after their initial questions."
- "One group sat there with 5 questions, other groups went a lot further, so we did
 a quick gallery walk so they could look at the other groups, and then gave
 them another 2-3 min to add a few more questions."

Classroom Example: High School Chemistry

<u>Teacher:</u> Sara Stephenson

<u>Topic:</u> Physical and chemical properties and changes

<u>Purpose:</u> For students to plan and perform an investigation to test/answer one of their priority questions

Question Focus



Student Questions

- 1. What are the substances?
- 2. Why does it change colour?
- 3. What can we do to determine what the substances are?
- 4. How did the clear liquid affect the chemical change?
- 5. Does there need to be a specific measurement of the liquid and powder to ignite?

6. Does it change colour because it's heated?

7. What causes the flame to go out?

8. Are the substances in the watch glass flammable?

9. How much liquid was in the beaker?

10. Does the colour of the solid impact the flame colour?

Students' Priority Questions

- 1. What are the substances?
- 2. What was the rope being soaked in?
- 3. Is there a chemical change occuring?
- 4. Why does it change colour?
- 5. Was the clear liquid flammable or was it the substances in the watch glass?
- 6. What can we do to determine what the substances are?
- 7. What causes the different colours?
- 8. How did the clear liquid affect the chemical change?
- 9. How much of each substance was used?
- 10. Why does it become a coloured flame and not a regular flame?
- 11. Does there need to be a specific measurement of the liquid and powder to ignite?
- 12. Does it change colour because it's heated?

Next Steps with Student Questions

• Students prioritized questions based on actions they wanted to take

Examples: the 3 most important questions at this time, 3 questions you would like to address first, 3 questions you want to explore further

• In groups, students determined which of their priority questions were testable questions or re-writing to turn into testable questions

Definition of testable questions: they are always about changing one thing to see what the effect is on another thing. We have to be able to perform an experiment to determine if it's true or false.

Priority → Testable Questions

- Does changing the amount of liquid affect the size of the flame?
- How does changing the substance affect the colour of the flame?
- If the rope is changed, will it affect the flame colour/size?
- Does changing the room temperature affect the flame size/colour?
- If we were to change one solid, would it affect the flame height?
- Does changing how much liquid was used effect how long the experiment lasted?

Next Steps with Student Questions

- After picking one of their testable questions, student groups designed an experiment to test it
- Groups were prompted to complete a worksheet to help design the experiment:
 - Purpose
 - Hypothesis
 - Materials needed
- Students created a table to record their observations
- Finally, students analyzed their results and explained if their prediction was correct or not

<u>Purpose:</u> Why are you doing this experiment? What are you trying to find out (To determine if the colour of the solid impacts the flame colour of the substance)

<u>Hypothesis:</u> If the colour of the solid is compared to to the flame colour, then ...

Materials:

- Compounds listed in observations
- Hydrochloric acid
- Nicrome Wire
- Bunsen Burner
- Flint Lighter

Observations:

Table 1: what is in your table?

Comparison of solid colour, experimental flame colour and theoretical flame colour for various ionic compounds.

| Chemical | Color of solid | Experimental Flame colour | Theoretical flame colour |
|------------------|----------------|------------------------------|--------------------------|
| Lithium chloride | | | |
| | | | |
| | | | |

Classroom Example: High School Environmental Science

<u>Teacher:</u> Sara Stephenson, Ontario, Canada

<u>Topic:</u> Climate change

<u>Purpose:</u> To generate questions of interest for a mini research project

Question Focus

River 1, position 16, altitude 707 m, Greenland ice cap melting area],



Student Questions

- 1. How cold is the water?
- 2. Is there any animals there? or people?
- 3. Why did the water melt in a cold area?
- 4. How might global warming affect the glacier?
- 5. How warm/cold is it?
- 6. Why didn't the snow melt with the water?
- 7. How much has the temperature changed?
- 8. Why is there snow if the ice is melting?
- 9. Is the ice melting?
- 10. How fast does the ice melt?
- 11. Is the change in temperature the cause of the ice melting?
- 12. How long does the water go for?
- 13. Is this natural?
- 14. Where was this picture taken?
- 15. Is the water getting deeper?
- 16. Or does it drain somewhere?

18. What is the black stuff?

- 19. How dense is the atmosphere there?
- 20. Did it always look like this?
- 21. How long does it take to melt?
- 23. What time of year is this?
- 24. Is it ever sunny out?
- 25. How thick is the glacier?
- 26. Does it get thinner when it melts?
- 27. Is the environment dying?
- 28. What is the average temperature for each month?
- 29. Where does the water lead to?
- 30. How fast is it melting?
- 31. Is the ice melting?
- 32. What is under the ice?
- 33. How does ice melting affect humans?

Next Steps with Student Questions

How Might Global Warming Affect The Glacier?

As the Earth warms, the melt line moves upwards so that the glacier melts faster and faster at the bottom, shortening the glacier and reducing its mass. Ultimately, the melted water flows into streams and rivers and ends up in the oceans, contributing to accelerating sea level rise.



Students did
 internet research to
 answer a priority
 question and share
 in a class slide
 deck.

 Students created short 3-5 minute informative videos climate change & human health.

Teacher Reflections

- "Since I wanted to focus on climate change (a unit of study in our course) I laid more detailed groundwork before the QFT to shift the mindset of the students towards this topic. For example, we had some preliminary discussions looking at other images of how our planet is being impacted by rising global temperatures ... I find I get much deeper questions when we've zoned in on the topic first, before starting the QFT."
- "One of the reasons I love using a QFT is because it acts as both a diagnostic activity and lays groundwork for our next steps in a way that is very student-centered. I find that the nature of the questions that students ask is very indicative of what they already know about the topic. Using their priority research as a starting point for investigations and learning activities ensures that they are truly learning new things."

High School Biology

Teacher: Dr. Leah Cataldo Cambridge, MA

7 Properties of Life









Regulation: Jackrabbit



Energy Processing: Butterfly on flowers



Evolution and

Growth and

Development:

Oak Seedling

Response to the







- 1. Ask as many questions as you can
- 2. Do not stop to discuss, judge or answer
- 3. Record exactly as stated
- 4. Change statements into questions

There are seven properties that are associated with something being characterized as living.

Observe this figure that names each of the seven properties together with an *image that portrays* that attribute in living things.

Working with your partner over the next three minutes, write down as many questions as you can that come to mind based on those names and images.

Choose three questions that...

You can use the internet to explore. Bring what you learn to our next class (brief summary/bulleted list).

AP Biology

Teacher: Dr. Leah Cataldo Cambridge, MA

Introduction to Water Potential

Net water potential depends on the effects of both solute concentration Ψ_{π} and pressure Ψ_{p} .



- 1. Ask as many questions as you can
- Do not stop to discuss, judge or answer
- 3. Record exactly as stated
- 4. Change statements into questions

2021 Questions

- What is the relationship between [solute] and pressure?
- What is a scenario where osmotic potential is (-) and pressure potential is (-) but rising? ***
- · Why does concentration always have a (-) vector
 - Because adding solute lowers water potential
- · What is the water potential of pure water?
 - Zero, answered in the graph presented
- Does net water potential differ with different environmental conditions?
 - How does a change in ____ influence net water potential?***
- How do cells adapt to changes in water potential?

Classroom Example: AP Physics

- <u>Teacher:</u> Rachel Riemer, Cambridge, MA
- <u>Topic:</u> Bias in science

<u>Purpose:</u> To open up discussion around an important issue

Question Focus: Bias in Science

Philip Live Bias in Science EWhat is bias in science? Who is bias? OHow much does bios affect science? OWhen is bias?" E What is science? E What is bias? [Where is bias?" E. Is there always bias in science? Otlow is bian? E Where loes bias come from?" (Why is bias?) E How do you prevent bios ? Does biss influence science, OCan you prevent bias? or is it a port of it? OWhat role does bias have in science?" E Should we core about bios in science? When? E Are scientists biased?" OCan bias be helpful in science? O Can bias be hormful in science ?" O Can we measure bias? E Would the world change if there has no bias? Ottow much bios is in an average science? Obblot discipline of science has the most bias?" Other would the world change it there was no bias?"-OIs biss in the experimentation, or the presentation of result?" Els bias human error ?-> OAre humans responsible for their bias ?

Michael Kenijan W

Vtj Bias in Science Why would What is bias in science! O you bias What counts as bias of what is When does bias occur Acousts as Is all science biased. Obias? to wards things . What types of things would hold biases about and my What isn't bias? 0 · Why are people biasel · And why are people not brased ? O . How do highschoolers stop bias () How do scientists use bias · Is anything no thiasel G What isn't biased in science () · Can bias ever be eximinated @ · whattypes of science tare the most bias? C Climate change is a thing? O Man you write vinayak next to that? C . How long have we done bias? O How long have we been brased !! . How do we reduce bias? () What next? C · Do people working in crime forensis labs raise bias? . What types of ethical difenmas does that mise? O How do we relate this to alab ?? · To overlas? when does that mean? C . Is there bras in the scient i'fi'c method? A new eusing bias right now? O Is bias gool? O what is buo about bins? C ·canbias be good! when!

Bias in Science C=closed 0=open ** 0 - How are scientists affected by bias O = What is bias 0 - how do Scientist's biases affect Lablexperiment results 0 - how often is bias represented in resultr O = how do we design experiments to be bias free O how can we dublee 050 our expirements with higs in mind o/c =are all scientists affected by bias 0 - What recent scientific discoveries have been informed by bigs olc = is scientific bias dangerous O = What gre scientists biased by * C = are numbers subjected to bigs 0 = what specific part of an experiment is most easily influenced by bias o mat which stage in the scientific method is bigs most in fluen tial O = What can de to prevent bias in future O = which occus more: experiments affected by blas or appelments designed that based on bras * 0 - what effects can bias have on numbers and exportmental data * c - what is an example of an instance where scientists were affected by bias · Eliminating bias · Causes of bigs · Effects of bigs Nature of his

Student Questions

- What are some occurrences? 1.
- What topics in science have most bias? 2.

How is bias defined? 3.

- Are there different types of biases in 4. science?
- How does bias affect experiments and 5. results?
- How does bias influence data 6. collection?
- Is it possible to be completely bias free? 1.
- How to reduce bias? 8.
- 9. Why is there bias?
- Is bias intrinsic? 10.
- 11. 12.
- Is bias necessarily bad? How important is the fact that there is bias? (O)

13. Is it important that there is bias? (C)

14. When in history did bias in results of experiments affect the public?

15. How do you quantify bias?

- 16. What increases/decreases bias?
- 17. What is the trend of bias in science? More? Less?
- 18. Are certain groups of people more easily biased? (C)
- 19. What are the certain groups of people? (O)
- 20. How can we eliminate bias in high school experiments w/o high tech?
- 21. What's in place now to reduce bias?

Next Steps with Students Questions

- Students identified patterns that emerged from their questions
- They categorized their questions into those patterns
- Students' priority questions were used as a class discussion activity

- buckgrown Prompt: Blas in Science History Elwhoe are some ocurrences? delinitio Elwhat topics in science have most bias? () Erlaw is bias defined? >> 0 14- examples IPR there diff types of biases in science? C How does beas affect results? M-impact Capenments + help/reduce MI-patterns/trends influence acta collection 0 Is it possible 26 completely bias-free? Dec Etlows reduce beas? O Elwhy is there bias? O Els bias intrinsic? C Els bias nucessanly bad? C E How important is the fact that there is blas? () I the important that there is brass? C when in mistory did blas in experiments affect \$ Public? 0 results of E How quantify blas? () Divinue in creases/decreases 61as? 0 = What is the trend of bias in some ? More? less DAre certain groups of pp1 more easily brased? What are the certain groups of pp1...? O

Conta Ettaw can we eliminate bias in high school experiments who histern? Elwhats in place now 2 reduce blas? () Our 3 ?s and why they're important/why we're interested - How is bias defined 4 fundemental question 4> Dictates how we interpret further exploration - History result experiment affect public 4 We could be living in a skewed world 17 did it affect pp1 disproportionally 47 does it create distrust blw public and science work - Diff groups of people - bias

History/definition

- How is bias defined?
- Why is there bias?
- Is bias intrinsic?
- Is bias necessarily bad?
- When in history did bias in results of experiments affect the public?
- How do you quantify bias?

Examples

- What are some occurrences?
- What topics in science have most bias?
- Are there different types of bias in science?

Impact

- How does bias affect experiments and results?
- How does bias affect influence data collection?

Help/reduce

- Is it possible to be completely bias free?
- How do you reduce bias?
- What increases/decreases bias?
- How can we eliminate bias in high school experiments w/o high tech?
- What's in place now to reduce bias?

Patterns/trends

- What is the trend of bias in science? More? Less?
- Are certain groups of people more easily biased? (C)
- What are the certain groups of people? (O)