CHEMISTRY VIDEO CASE

Behavior of Gasses
11th grade Chemistry
Bethany, 2nd year teacher

School demographics
Students Receiving Free/Reduced Price Lunch: 63.9%
English Language Learners: 7.9%
Students of Color: 74.8%
Special Education Students: 13.6%

Selecting big ideas, treating them as models

Traditionally in Chemistry students learn about the behavior of gasses through investigating gas laws. But a law is a description of a phenomenon and if taught through a "lens of laws" students focus their attention on correlations among variables. For example, as pressure increases volume decreases. Theories provide explanations for laws. Explaining gas laws requires a keen understanding of molecular movement and how energy influences this movement. One of the challenges is that many of the gases we interact with one a daily bases are not visible. For this unit of instruction Bethany chose to have students reason with a familiar gases first: air and steam. She posed a puzzling phenomenon about an oil tanker that collapsed after being steam cleaned and sealed. Students developed initial models about what could cause the tanker to collapse and then did experiments with pop cans crushing with the aid of steam to add to the initial models. The pop can experiments helped students link an observable phenomenon with theoretical components such as the role of phase changes and the speed of gas molecules but to reason with the role of pressure inside and outside of a system; students did additional experiments and read about pressure. Over time students constructed a rich explanation for the oil tanker collapsing, while also considering similar phenomena. Students were then ready to apply what they learned to less similar observable phenomena. Bethany chose a set of relevant phenomena to students' lives and had students explain modifications made to race cars based on their understanding of the gas laws. Students could choose to think about modifications to tires or engines.

Focus on topic or "things"	**Focus on observable processes**	**Explanatory model focus**
• Teacher selects concrete or abstract entities (things) to learn about in varying degrees of detail. • Students asked to describe, name, label, identify, using correct vocabulary.	• Teacher selects as focus "what is changing" in a system or how conditions affect a naturally occurring event.	• Teacher focuses on *unobservable* processes, events, or entities, or the relationships among science concepts. • Teacher links these to important *observable* natural phenomen**a** in order to develop an explanatory model that students will make sense of over time.

Attending to students' ideas

Bethany attends to students' ideas in several ways. First she plans daily activities based on what will help students build a scientific explanation. She has a general sense of the activities that fit with the big idea but is open to rearranging, adding, or subtracting activities based on what she hears students reasoning with or only partially reasoning with each day. Her "warm-ups" are responses to what she heard the previous day. She also plans each day by listing a set of probing questions to ask students and ideas she will be listening for. Here is an example of her plan for the first day of the unit:

Phase of Unit	Day	Goals/Purpose	In Class Activities/Conversations	Student Work
Eliciting Student's Ideas	One: The Tanker	1. To get students' ideas on the table about the relationships between temperature, volume and pressure in gases. 2. To hear their everyday language about temperature, phases and pressures. 3. To hear any preconceptions about pressure and forces.	Students will observe video clip and picture of crushing tanker in order to elicit their ideas about the relationships between temperature, pressure and volume in gases. ** Spoken probing questions: • What is inside the tanker? • Draw the molecules, show their actions. • How much stuff is in the tanker? • Why does it collapse (show with arrows) • What do you mean by "suck?"	Individual brainstorm about what/why/how the tanker is collapsing. Group poster explaining their ideas about what's happening to the tanker. ** Expect to see/hear: Students should be talking about molecules, and should make connection temperature and speed of molecules. They should also talk about molecules spreading out as they heat up. Students should use arrows of varying lengths to represent speeds of molecules. They may or may not start using arrows to represent air pressure on the outside of the tanker. They might talk about the walls of the tanker being "sucked" in.

In conversations with students Bethany assumes there is more than one right way to assemble an explanation. She follows students' lines of thinking and presses students to put all of their ideas on the table so she can fully understand not just what but how students are reasoning with the explanation. Most often you will hear Bethany asking students 5 why questions for every 2 word response they give. Once she understands students' explanations she asks them to wrestle with a new idea or to figure out how to piece together 2 different ideas students in a group raised. One indicator that students are constructing an explanation that makes sense to them is that each poster students develop looks slightly different, even at the end of the unit. Not only does Bethany work on students' ideas but she supports students in working on their own ideas by having them constantly track their ideas on a scientific model.

Monitoring and re-teaching ideas	**Eliciting students' initial & unfolding understandings**	**Referencing students' ideas & adapts instruction**
• Teacher starts by presenting information, then monitors language students use to see if students are developing "correct" conceptions (whether students "get it" or not). • Teacher engages in 1-on-1 tutoring or uses IRE in whole class conversations to present more correct conceptions to students (perhaps using a different modality).	• Teacher elicits students' initial and on-going hypotheses, questions, or conceptual frameworks about a scientific idea.	• Teacher elicits students' initial conceptions of a scientific idea by posing a rich open-ended task or puzzling event related to the big idea of the unit. • Teacher listens for partial understandings as well as alternative conceptions (without presuming students need to precisely replicate the teacher's line of thinking). • Teacher uses students' language and partial understandings as building blocks to shape the direction of classroom conversations. Teachers engineer productive classroom conversations or pursue students' lines of thinking by weaving students' lines of reasoning together with scientifically coherent ideas across multiple lessons.

Choosing activity and framing intellectual work

Bethany chooses activities to help students build an explanatory model. Students begin with a simple model and after each activity has students' add to their initial models. Ideas from these models are used to explain a class of phenomena, not *a* phenomenon. Students use models the way scientists do: to explain and predict.

Primarily focusing on procedure	**Discovering or Confirming Science Ideas**	**Linking concepts within and across investigations**	**Model-Based Inquiry focus**
• Teacher asks students to describe procedures for activities or experimental set-ups. • Science concepts are played down to allow time to talk about designing experiments. • Talk with students is about how to do an activity or about error, validity, reliability, recording data.	• Teacher has students "discover" science concepts for themselves OR has students use an activity as a "proof of concept." • Science is about acquiring accepted facts, principles, or laws. Students collect information to recognize or prove patterns.	• Teacher first seeds students' thinking with new science concepts (not explanations) and asks students to use these ideas to makes sense of an investigation. • Science ideas are up for discussion. Students derive explanatory language from activity and use it to solve new problems. Public representations of students' ideas change in response to findings from each day.	• Teacher highlights tentative or partial explanatory models as the basis for multiple investigations. • Teacher asks students to use evolving model as a reference before, during and after each inquiry. Teacher builds in background knowledge of underlying (unobservable) science ideas and models before, during, and following an inquiry, but without doing the reasoning for the students. • Science is about revising and testing models to synthesize ideas and explain problems.

Pressing for explanation

Bethany's practice is characterized by a constant press for why explanations. Each activity aims to add to an explanation and each interaction with students either starts with a press for why or help students first explain what and how then why. Students constantly transition back and forth between observable and unobservable features of an explanation. She has two main ways in which she supports students in constructing rich explanations. First, she uses explanation checklists. These are a combination of ideas she would like students to include in an explanation and ideas students think they need to include. Activities are used to build ideas for a checklist. Second, she uses sentence starters. This was a practice Bethany found necessary when teaching overseas with students learning English, but she finds it to be an important structure for all students. The sentence starters often give students an either-or choice at the beginning of a sentence but the end of the sentence is left open-ended so students need to synthesize a why explanation. Here is an example from the car modification explanation. Students worked in small groups to complete these sentences.

The ____________________ increased the power of my car because it ______________________________.
Which modification? Brief description of modification.

During the intake stroke**, the # of molecules of air** in the cylinder **increased/decreased** compared to a regular engine because _____________________.

During the intake stroke, **the temperature of air** in the cylinder **increased/decreased** compared to a regular engine because ______________________.

During the compression stroke, **the pressure of air** in the cylinder increased/decreased compared to a regular engine because _________________________.

During the combustion stroke, **the rate of expansion of the air** in the cylinder **increased/decreased** compared to a regular engine because___________________.

Students have scaffolding for easier parts of the explanation so the emphasis in group work is on wrestling with unobservable processes. In this way she models for students how to piece together a complete causal story.

Part of the reason Bethany is able to track students' construction of causal explanations is because she frequently examines students work to see which parts of a causal explanation students are working on. Here is Bethany's analysis of 5 students' work for the "pop can activity" on Day 2.

	Level 1 **"What happened" explanation**	**Level 2** **How/ partial why something happened explanation**	**Level 3** **Causal explanation**
	Student describes that the tanker imploded following cleaning and being sealed. Student describes pressure as a collapsing force. Student recognizes phase changes are important to implosion.	Student describes ideas related to kinetic molecular theory (faster molecules with more energy) and an increase in pressure but leaves out the critical step of describing how the type of molecules and number/force of collisions are important for maintaining/ changing pressure.	There are air molecules inside and outside of the oil tanker. Steam cleaning adds water molecules that move at a high speed and collide with the interior wall. Prior to being sealed high-energy air molecules are driven out of the tanker. After sealing the tanker, there is no gain or loss of molecules on the inside. The steam and air molecules on the inside lose energy as it cools and there are fewer collisions in the interior. Pressure decreases on the inside but pressure on the outside remains the same (14lbs/in^2). With less pressure, the tanker collapses to maintain equilibrium. Student recognizes differences in pressure inside and outside of the tanker and the balance of forces. Student describes what causes pressure. Student weaves together the ideas that as molecules change temperature the speed changes, and thus the number and force of collisions changes, which changes pressure.
CB		+ Reasons about pressure differences. States relationships between temp. and pressure and volume. Never mentions collisions.	
AC			Repeatedly explains relationship b/t speed and collisions, pressure and phase change. Never states what outside pressure is from.
JZ	Some confusion about types of molecules.	Phase changes pressure equilibrium- some	
HC	States air outside causes pressure. Describes speed/temp/collisions No explanation of pressure balance.		
JH			Repeatedly thinks about balance of pressures and the movement of molecules. Never states what is causing pressure outside.

Bethany used a similar rubric to formally examine student thinking on a quiz she gave to students at the end of this unit. Samples of student work on this quiz can be accessed on the website so you can also examine how these students' ideas changed over time.

"What happened" explanation	"How/ partial why" something happened explanation	Causal explanation
• Teacher asks students to describe relationships between variables, differences between experimental groups, trends over time, or qualitative observations. "Explain what you see in the data."	• Teacher asks students to hypothesize about reasons for relationships among variables or observations, and how these predict the ways some natural system will behave.	• Teacher has students use unobservable events, processes, and entities to construct a causal story of why something happened. (may mean first supporting students through "what" and "how explanations" with goal of working toward "why explanations") • Teacher unpacks learning about the nature of scientific explanations with students, and about "what counts" as evidence.

Planning with and for causal explanations of puzzling phenomena: Gas Laws Unit

Phenomena:

Oil tanker implosion-After being steam cleaned and sealed an oil tanker imploded.
Essential question: Why did the oil tanker implode after steam cleaning?

Explanatory Model:

There are air molecules inside and outside of the oil tanker. Steam cleaning adds water vapor molecules that move at a high speed and collide with the interior wall. Prior to being sealed high-energy air molecules are driven out of the tanker. After sealing the tanker, there is no gain or loss of molecules on the inside. The water vapor and air molecules on the inside lose energy as it cools and there are fewer collisions in the interior. Pressure decreases on the inside but pressure on the outside remains the same (14lbs/in^2). With less pressure, the tanker collapses due to differences in pressure.
Charles Law stipulates the relationship between temperature, volume and pressure. If temperature increases, then either the volume or the pressure (or some combination of the two) will increase. The opposite is also true. If temperature decreases, then either the volume or the pressure (or some combination of the two) will decrease. Pressure will only increase if the volume is held constant. In a flexible container, volume will increase (pressure remains constant). In a closed and rigid container, volume (ideally) stays constant and pressure increases instead. From a molecular point of view: increasing the temperature of a gas causes the molecules to move faster, hitting the sides of the container or closed system more frequently and with more force. Pressure is defined as force per unit area, the area that the gas is in contact with must increase as much as the force of the molecules hitting the container does.

Activities & Readings (link these to unobservable features in the explanatory model)

- Can crushing—similar phenomena helps students reason with phase changes & Kinetic Molecular Theory but doesn't get at internal/external pressure
- Balloon sucked into flask with change in temperature- similar to can & tanker but students can better see what is going on inside the flask/can/tanker and reason with changes in pressure inside versus outside
- Marshmallow shrinks in plunger- with a decrease in volume there is an increase in air pressure
- Sucking air out of a flask lowers the pressure inside, outside remains constant, to achieve equilibrium more air enters flask
- Reading on pressure—what it is and how differentials are established
- Readings on gas laws (Charles, Boyle & ideal gas law) & relational causality
- Draw on Kinetic Molecular Theory from previous unit
- Readings on modifications made to race car engines & tires for application to new phenomena

Gas Laws Unit Plan

Lesson	***Activities***
Pre-teaching interview	
Day 1 Eliciting students ideas about gas behavior Discourse Tool #1: *Eliciting students' hypotheses to shape instructional decisions*	1) *Elicitation of student ideas.* Describe what you already know about how gasses behave. (Think about: How do they move? What affects their movement? What is a gas?) 2) *Explaining an oil tanker crushing phenomenon.* Students watch video. Unprompted they start thinking about why this happened. Students then record initial ideas. Students then work in groups to draw before, middle and after pictures. 3) *Whole-class debrief.* Students share posters of their initial ideas. 4) *Homework:* Students did a reading about the behavior of gases. *Discussion Questions: 1) What general ideas do most students seem to have about the behavior of gasses? Which of these ideas can be built on? Complete RSST tool.* *2) How does Bethany uncover students' ideas? What kinds of questions does she ask when students give incomplete responses or reveal an alternative conception? What does she do when she first enters a group/ exits a group?*
Day 2 Building an initial consensus model and linking together parts of the causal story Discourse Tool #1: *Eliciting students' hypotheses to shape instructional decisions* Discourse Tool #2: *Making sense of material activity*	1) *Warm-up, Day 2.* Yesterday you heard different groups present their ideas about why the tanker crushed. You also read about the behavior of gases as homework. What are 3 new ideas you have about why the tanker is crushing? Teacher reviews student ideas from previous day. 2) *Making an initial consensus model.* Teacher reviews student posters using 2 guiding questions: A) Make a list of what's causing the tanker to crush. B) Does anything seem to be linked together? Does one thing happening seem to cause another thing to happen? 3) *Pop-Can Activity*: Back pocket questions are used to a) help students link together parts of the causal story b) identify gaps in the students' causal stories and c) help students begin to think about how they could further study the phenomenon. *Discussion Questions: 1) In the video Bethany works with two groups as they consider the relationship between phase changes and pressure changes. How does she tailor her back-pocket questions in response to each group's line of thinking? 2) Examine 6 samples of student's pop can activity and record students' partial understandings.*
Day 3, 4, &5 Explaining pop can crushing Discourse Tool #2: *Making sense of material activity*	1) *Warm-up, Day 3.* "How is the pop can similar to the crushing tanker? How is it different?" 2) *Examining variables.* Teacher helps students hypothesize about 5 experiments inspired by student ideas from the previous day. 3) *Pop can Activity II*. As students conduct experiments the teacher poses back pocket questions to a) help students link together parts of the causal story b) help students identify gaps in their causal stories. • Experiment #1: Amount of water in the can • Experiment #2: Temperature of the water bath • Experiment #3: Amount of time on the hot plate • Experiment #4: Volume of the can • Experiment #5: Amount of seal 4) *Warm-up, Day 4*. Teacher prompts students to consider 4 key ideas in their explanations. The warm-up asks students to "Choose one of the following ideas and explain how it relates to the experiment you did yesterday. • Temperature change- speed of molecules • Temperature change- phase of matter • Pressure inside • Pressure outside 5) *Complete pop can Activity II.* As students finish experiments the teacher poses back pocket questions to a) help students link together 4 parts of the causal story. 6) *Warm*-up, Day 5. Think back to your experiment with the cans. State your results as a rule. How did changing the manipulated variable affect the amount of crushing? When _________________the can crushed more because ____________________. 7) *Reporting out and connecting experimental findings.* Teacher coordinates discussion of findings across groups. Teacher describes what happens and presses student to say why. *Discussion Questions: 1) Record the questions Bethany asks, group them into conceptual categories, and then consider her reasoning for asking these rounds of questions in this particular order. 2) Which questions seemed to be most productive for helping students move their thinking forward?*

Day 5 & 6 *Increasing content understanding about air pressure (as opposing forces) and relationships with volume, and temperature.* *PV=nRT* Discourse Tool #2: *Making sense of material activity*	1) *Increasing content understanding about air pressure.* Students struggled to reason with internal and external air pressure. Teacher reviews homework assignment about pressure. Teacher has students show work to class as a way to "work on student ideas." Then teacher helps students reason with forces and pressure. 2) *Balancing Act.* Teacher asks students to reason with number of molecules, temperature, volume, and pressure (in terms of pulling and balancing internal and external pressure) throughout 4 experiments. • Station 1 Balloon Blow up • Station 2 Marshmallow vs. Pebble • Station 3 Expanding Balloon • Station 4 Balloon in Flask 3) *Warm-up, day 6*. Draw a diagram to explain why this tire would inflate. Draw the air molecules outside the tire, Draw the air molecules inside the tire. Use arrows to indicate where pressure is higher or lower 4) *Returning to air pressure experiments and explanations.* Students completed diagrams and questions for the air pressure experiments. *Discussion Questions: 1) What are different strategies Bethany uses to plan for as well as in-the-moment work on students' ideas? 2) What kinds of ideas do students wrestle with during the experiments? Do the conversations move beyond procedural talk? When, how?*
Day 7 &8 Applying new ideas to a model Discourse Tool #3: *Pressing students for evidence-based explanations*	1) *Warm-up, day 7.* Students review air pressure experiments. Specifically the relationships between pressure and the a) number of molecules, b) volume and c) temperature. 2) *Adding to the model.* Teacher facilitates a whole-class discussion about the information that needs to be added to their initial model. Then students work in small groups to add to their models of the can crushing for the experiment they conducted. NOTE: The teacher notices students are trying to apply ideas about kinetic molecular theory to the can crushing experiment. They reason with partial understandings about the speed of molecules, how the temperature influences speed, why the space is important to molecular movement. The teacher helps students link these ideas to the experiment but also directs their focus to a different but related underlying explanation (the number of molecules) to explain why the can crushes. 3) *Warm-up, day 8.* In response to how students were reasoning with molecules, the teacher designed a warm-up to help students think about the number of molecules at each stage in the can crushing. "Say I started with 10 water molecules (X's) in the bottom of the can and 20 air molecules (O's) in the can and then I heated it up to boiling and let it boil for 2 minutes. Draw a picture of a can and mark where you think the X's and O's would be after these 2 minutes." *4)* *Adding to the model.* Students return to diagrams and continue to add information to their models using a checklist with key concepts for the students to include. *Discussion Question: 1) How is the explanation check list developed? How is it used? 2) Generally speaking, compared to days 1 & 2 how have students built on their original ideas? And what new ideas are they entertaining now?*
Day 9 *Increasing content understanding about number and speed of molecules and relationships with pressure, volume, and temperature.* *PV=nRT* Discourse Tool #3: *Pressing students for evidence-based explanations*	1) *Warm-up, day 9.* The teacher asks a warm-up that helps connect ideas about kinetic molecular theory with the gas laws. "When you flip over the can into cold water, describe what happens to the PHASE and SPEED of the gas molecules (both X's and the O's) inside." 2) *Pressure and Collisions.* Students talk about correlations between pressure and number of collisions on a container and then reason with three ways the pressure/number of collisions can decrease—the amount of space (V), the number of molecules (n) and the temperature (T). Students then look at these relationships in a computer simulation. http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=25 3) *Can you compress water?* Teacher helps student reason with the differences between air molecules and water molecules. Need to think about pressure of water in can puts on the can and why this is an important part of the explanation for why the can does not crush. 4) *Return to posters to add new knowledge.* Teacher highlights 2 parts of the explanation checklist that students are generally not attending to in their explanations. She also provides each group with 3 sheets of fill-in-the-blank sentences to make sure students are reasoning with a full explanation for each of the 3 can crushing stages. *Discussion Questions:1) Bethany adds an additional scaffold to the check list by giving students sentence starters. How does this shift the ways students participate in class?*
Day 10, 11 & 12 *Generalizing to the behavior of all gases* Discourse Tool #3: *Pressing students for evidence-based explanations*	1) *Piecing it all together.* Teacher facilitates whole class conversation of a full explanation of the tanker crushing. 2) *Review of learning.* Teacher has students refer back to initial explanations. 3) *The Behavior of Gases.* Teacher reviews general ideas about what influences the behavior of gases and bridges to scientific language. Then the teacher introduces the Ideal Gas Law. 4) *Focus on correlation between P & V.* Pressure Volume Student do activity with syringe and scale to examine the relationship between P & V. Students graph results and talk about an inverse relationship. 5) *Warm-up, Day 11.* Explain from data the previous day how we know that pressure and volume are considered inversely proportional.

	6) *Review lab and introduce Boyle's Law.* Teacher introduces the idea of P1V1=P2V2. Teacher asks questions that help students reason conceptually and mathematically with the equation. Students then record notes on a master table with the ideal gas law broken down in to 3 different relationships. 7) *Volume and Temperature.* Teacher introduces the idea of Kelvin by having students think back to volume and pressure lab and whether or not 0 pressure or 0 volume is possible. Students then do mathematical calculations to examine the relationship. 8) *Warm*-up*, Day 12*. Your car tire ahs 10L of air and it's 0 degrees Celsius outside. Later that day the temperature has increased to 26 degrees Celsius. What will happen to the volume of the tire? Why? 9) *Review of Volume and Temperature.* Students take notes on Charles's Law. V1/T1=V2/T2. 10) *Pressure and Temperature.* Students take notes on P1/T1=P2/T2 and then do practice problems. *Discussion Questions: 1) Thought experiment: Typically in Chemistry students learn each gas law and do calculations. Compare this to Bethany's "concept first" approach. Also think about the difference between learning about a theory about the behavior of gasses versus laws.*
Day 13 & 14 Applying gas behavior principles to car engines Discourse Tool #3: *Pressing students for evidence-based explanations*	1) *Warm-up, Day 13*. What are the gases in the engine? What gas(es) are present during intake, compression, combustion, and exhaust? 2) *Engine Modification Challenge.* Students select 3 modifications and describe why each modification helps a car have more power. They also need to describe why a pressure sensor is needed on tires. Students read background information on each modification and complete a fill-in-the-blank form that helps students reason with P,V,T and n. -tire pressure monitoring system -bore out cylinders -cold air intake -high performance exhaust system -intercooler -nitrous oxide system -turbocharger -supercharger 3) *Warm*-up*, Day 14*. Why is getting more oxygen into the engine beneficial? (Think about the combustion reaction). 4) *Summative assessment. Gas Quiz.* *Discussion Questions: Examine students' responses on the Gas Quiz. Question 8 is an application to a different phenomenon and question 9 is an opportunity for individuals to express a full causal explanation for the pop can crushing. Compare responses for 8 & 9 and for AC, HC and JH compare their response on question 9 to their assessment on day 2.*
Post teaching interview	