1. Overview
I have noticed my students struggle to fully and internally grasp concepts that they truly cannot see. The nature of the chemistry is difficult in itself being that chemists seek to provide an explanation of the behavior of matter at an atomic level, which of course cannot be observed by the naked eye or even through a microscope. The learning activities done in my classroom did not require students to think beyond the observable. To fully understand the observable, students need to envision the unseen. Without the understanding of the “unseen”, students are not easily able to connect ideas and adequately explain the concepts they are learning and investigating.

To tackle this struggle I had my students observe concepts or phenomena and draw detailed diagrams to provide explanations of what was taking place at the atomic (unseen) level. “A full explanation is a causal story that describes why a phenomenon occurs. To connect this explanation to evidence from an investigation, it is helpful to outline or diagram what is observable or measureable and then draw in features and processes that are not observable – thus creating a scientific model for the phenomenon under study.” (Thompson, in press)

After drawing diagrams and providing explanations I engaged students in a process of self-analysis where they compared their diagrams and explanations to mine. My diagrams and explanations were given at three levels of achievement; Level 1 being the most basic, Level 3 the most detailed and exemplar.

2. Research Questions
Overarching Question:
- In what ways has diagram and describing and self-analysis impacted student learning?

Sub-questions –
- What is the effect of this method on my students’ ability to answer test questions?
- In what ways does this method affect student work on daily assignments and classwork?
- What are my students’ feelings regarding this method and its impact on their learning?

3. Context
This research was conducted in three sections (68 students) of Regents Chemistry at Rush-Henrietta Senior High School. Students range from grades 10 – 11. The majority of students have already taken two years of Regents level science including Regents Living Environment and Regents Earth Science. The district accelerates all students in science meaning that all students take Regents Earth Science in 8th grade. The ethnicity of my students is relatively heterogeneous. I have a mix of Caucasian, African American, Hispanic, and Asian students.

The type of instruction that normally takes place ranges from direct, whole group, lecture and discussion, individual investigation of concepts, collaborative work and problem solving in small groups, to rigorous laboratory experiences. Class usually begins with a whole group introduction to what question / concept will be investigated that day. After the introduction students are given the remainder of class to conduct their investigation. Students work independently (not necessarily alone, just without me) and are required to be very in charge of the pace at which they progress through activities and learning of concepts. Students are very responsible for their own learning. They self-assess often and know to not move on until they fully understand the topic at hand. The classroom environment is very supportive of a collective learning environment where students and teacher can work together to solve a problem or figure out a concept. There are usually a variety of different activities taking place at a given time in the classroom. For example, some students may be
working on a lab, some may be getting a mini-lesson from me, others working in their seats on a practice worksheet.

I am a graduate from SUNY Geneseo, currently pursuing my MS-ED at SUNY Brockport and University of Rochester. I am currently in my fourth year of teaching at Rush-Henrietta Senior High School. I am currently teaching Regents and AP Chemistry. I have also taught local, non-regents level chemistry.

4. Methods

Students participated in a variety of experiences that required them to diagram and describe scientific phenomena.

1.) Gas Law Notes
   - Students were required to diagram and describe three relationships that explain gas particle behavior under specific conditions of temperature, pressure and volume. This diagram and describe was conducted as a whole group discussion. Each relationship was demonstrated by me, students were given time to diagram, describe, explain in words, then the relationship was discussed as a class.
   - Students were given time after the whole class discussion to add to their diagrams and explanations.
   - Key Concepts: Relationships between variables in relation to gas particle behavior: temperature vs. volume (flexible container), pressure vs. volume, temperature vs. pressure (rigid container). Defining air pressure. Ideal gas properties.

2.) Lab #4.1 – Behavior of Gas Particles
   - Students diagram and describe phenomena taking place at each station of a laboratory investigation regarding behavior of gas particles.
   - Analysis of these explanations was done by me. I made comments and returned the labs to students.
   - Key Concepts: air pressure, nature of gas particles (mass, and definition of a vacuum), variable relationships: temperature vs. volume (flexible container), pressure vs. volume.

3.) Hot Air Balloon Launch – Warm up
   - Students complete a diagram and describe as a warm up activity to explain how a hot air balloon is able to launch.
   - This concept was discussed as a whole group. Students were able to add to their diagram and explanation after the whole group discussion.
   - Key Concepts: density of gas particles, temperature vs. volume of gas particles, air pressure.

4.) Sky Lantern Demonstration – Quiz
   - Students complete a diagram and describe while watching a sky lantern launch. This diagram and describe is used as an assessment of student knowledge and understanding.
   - This diagram and describe was graded by me using a rubric of Level 1, 2, 3 explanations. Student explanations were scored as a 1, 2, or 3. My Level 1, 2, 3 rubric was made available to students for self-analysis and reflection. Self-analysis and reflection were not mandatory.
   - Key Concepts: density of gas particles, temperature vs. volume of gas particles, air pressure.

5.) Solutions - Why does a precipitate form? - Notes
   - Students complete a diagram and describe to explain why a precipitate forms when two solutions are mixed.
   - The diagram and describe is done as a whole group demonstration and discussion. Students were able to add to their explanations after the class discussion.
   - Key Concepts: dissociation of ions in solution, ion-solvent interaction, ion-ion interaction (solubility rules & Table F in Regents Chemistry Reference Tables), double replacement reactions.

6.) Strontium Flame Test Diagram and Describe Activity
• Students observe a flame test of the element strontium. Students diagram and describe how and why a red flame is produced.
• Students had already been exposed to this concept and its explanation. This diagram and describe served as a student self “check for understanding” of the key concepts.
• Students engage in self-analysis of their explanation by deconstructing Level 1, 2, 3 explanations produced by me. Once students have analyzed the different explanation levels they compare and contrast with their own explanation. Students rank their explanation and reflect on specific areas where their explanation could be improved.
• Key Concepts: atomic structure, electron configuration, excited state vs. ground state, absorption and emission of energy by electrons.

5. Data

Data to support sub-question 1: What is the effect of this method on my students ability to answer test questions?

Table 1: Midterm Exam Questions (Gas Law Unit)

<table>
<thead>
<tr>
<th>Question (Appendix A)</th>
<th>Key Concepts</th>
<th>Percent Correct (My 68 students)</th>
<th>Percent Correct (All 300 enrolled chemistry students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ideal gas properties</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>2</td>
<td>Ideal gas properties, temperature vs. volume (flexible container)</td>
<td>51%</td>
<td>54%</td>
</tr>
<tr>
<td>3</td>
<td>Ideal gas properties</td>
<td>74%</td>
<td>59%</td>
</tr>
<tr>
<td>4</td>
<td>Volume vs. pressure relationship</td>
<td>24%</td>
<td>35%</td>
</tr>
</tbody>
</table>

Unit 7 Exam: A question (Appendix A) that required students to explain how an element’s bright-line spectra is formed was analyzed in comparison to student responses on the flame test diagram and describe.

Data to support sub-question 2: In what ways does this method affect student work on daily assignments and classwork?

- Unsolicited diagraming on labs.
- Unsolicited diagraming on solution unit exam.

Data to support sub-question 3: What are my students’ feelings regarding this method and its impact on their learning?

Survey Questions: 63 of my 68 students answered the following questions on a written survey after completing the flame test diagram and describe activity.

1. Do you feel that diagraming and describing as affected your understanding of concepts in chemistry?
2. What do you like about diagraming and describing?
3. What don’t you like about diagraming and describing?

6. Analysis

In regards to the effect this method has on student ability to answer test questions it appears improvements are shown only when the diagram and describe prompt is almost identical to the test question. At RH, the chemistry content is presented in the same order in all classes. The delivery of the content is decided on by the classroom teacher. One midterm exam is given for all students in all chemistry sections. This allowed me to compare midterm results on specific questions. My students out-performed all other students on one question.

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The properties of ideal gases question. The question whose content was explored in the diagram and describe activities listed above. Analysis of the unit 7 exam question in comparison to the flame test diagram and describe also supports that students are able to answer test questions that are directly addressed in the diagram and describe experience. Additional analysis of the unit 7 exam question demonstrates retention of concepts and improvement of student explanations from the diagram and describe experience to the exam question. Students who rated themselves a 2 or higher on the diagram and describe showed little to no improvement in their explanation on the unit exam question. This supports that information was still retained and could be applied in a testing situation. Students who rated themselves a 1.5 or below on the diagram and describe showed significant improvement in their ability to answer the question on the unit 7 exam. Explanations on the unit 7 exam question were much more detailed, accurate, and incorporated more scientific vocabulary.

A rather surprising finding, one that I hadn’t initially expected was unsolicited use of the diagram and describe method as a problem solving tool. While grading labs that required students to writing double replacement reactions I noticed students using the diagram and describe method to figure out which ions combined to form a precipitate. I noticed this on 14 of my 68 students’ labs. Also, I noticed students using the diagraming method to help answer two questions on the solution unit exam. One question tested knowledge of ion dissociation and 8 of 68 students drew diagrams to help answer the question. The second question required students to write double replacement reactions (similar to the lab) and 12 of 68 students drew diagrams to help answer the question.

The majority of students, 86%, expressed that diagraming and describing improved their level of understanding of the chemistry concepts. Student A: “This affected it because it makes you think about what is really going on down to the littlest part and all the details that go with it.” The remaining 14% expressed their understanding was not impacted by the method. Student B: “This activity did not affect my understanding because I already knew the concepts. I did get to test out what I know though. Thank you.” No students expressed the method hurt or decreased their level of understanding. Most students expressed that they like completing the diagram and describe activities because it helps them give more detailed responses to questions. Student C: I like diagram and describe because it makes me want to give more than one word answers and really makes me think about my explanations. Students expressed that they did not like the amount of time it takes to diagram and describe as well as the amount of writing involved. Student D: “I don’t like the amount of writing.” Students also expressed not liking the repetitive nature of the activity. Student E: “We do too many diagram and describes.”

7. Conclusion and Questions for the Future
Diagraming and describing has proven to impact student learning in a number of fashions even in the short period of time this research has been conducted. Knowing that students generally feel the method is useful I’d like to further investigate its use to promote even more in depth understanding of concepts and student ability to transfer their knowledge to new situations and scenarios. Also, since the method requires students to give such detailed explanations I’d like to use the method as more of a formative assessment tool as opposed to teaching and student self-analysis. This method may also serve as an important collaborative tool for use between my entire chemistry department to indicate common gaps in student learning and initiate conversations on how to address these gaps.
Appendix A

Table 1: Midterm Exam Questions (Gas Law Unit)

1.) According to the kinetic molecular theory, the particles of an ideal gas
   a. have no potential energy
   b. have strong intermolecular forces
   c. are arranged in a regular, repeated geometric pattern
   d. are separated by great distances, compared to their size

2.) Which temperature change would cause a sample of an ideal gas to double in volume while the pressure is held constant?
   a. from 400. K to 200. K
   b. from 200. K to 400. K
   c. from 400.°C to 200.°C
   d. from 200.°C to 400.°C

3.) Under which conditions of temperature and pressure does carbon dioxide gas behave most like an ideal gas?
   a. low temperature and low pressure
   b. low temperature and high pressure
   c. high temperature and low pressure
   d. high temperature and high pressure

4.) A sample of a gas has a volume of 2.0 liters at a pressure of 1.0 atmosphere. When the volume increases to 4.0 liters, at constant temperature, the pressure will be
   a. 1.0 atm
   b. 2.0 atm
   c. 0.50 atm
   d. 0.25 atm

Unit 7 Exam Question:
In a laboratory, a glass tube is filled with hydrogen gas at a very low pressure. When a scientist applies a high voltage between metal electrodes in the tube, light is emitted. The scientist analyzes the light with a spectroscope and observes four distinct spectral lines. The table below gives the color, frequency, and energy for each of the four spectral lines. The unit for frequency is hertz, Hz.

<table>
<thead>
<tr>
<th>Color</th>
<th>Frequency (× 10^{14} Hz)</th>
<th>Energy (× 10^{-19} J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>4.6</td>
<td>3.0</td>
</tr>
<tr>
<td>blue green</td>
<td>6.2</td>
<td>4.1</td>
</tr>
<tr>
<td>blue</td>
<td>6.9</td>
<td>4.6</td>
</tr>
<tr>
<td>violet</td>
<td>7.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

38. Explain, in terms of subatomic particles and energy states, why light is emitted by the hydrogen gas. (2 pts)
References

