

Instructional Context

This introductory chemistry class consists of 18 students and exemplifies diversity in a small setting. Diversity arises in age, ethnicity, and prior knowledge. I have a total of 18 students: 8 White, 7 Black, 2 Asian, and 1 Hispanic; the class also divides into 8 tenth graders, 8 eleventh graders, and 2 seniors. While this is an ethnically diverse class, student's age is the more distinguishing characteristic. Younger students tend to be curious and bright while older students are looking for their 4th and final science credit. This broad spectrum of motivation for chemistry creates an interesting dynamic of give-and-take. As an accomplished science teacher, I am always making curriculum and syllabus adjustments due to varying student ages (**Standard D**). I reflect and evaluate information to meet and challenge the intellectual curiosity of my 10th graders as well as attempt to balance content in order to support the needs and spark the interests of my less motivated students. I have found that the most effective method of meeting both needs simultaneously has been by engaging the diverse ages through inquiry-based learning. Inquiry naturally challenges the intellectual curiosity of my younger students while also awakening the minds of my credit-bound-only students (**Standard VII**).

While none of my students are categorized as English Language Learners, Special Education, or even qualify for free/reduced prices, all 18 students were required to be enrolled in Algebra II or have already taken it. Consequently, I had no inhibitions about involving my students in an inquiry activity that was deeply embedded in math and chose to pair students with mixed abilities together to ensure that all students had the opportunity to succeed. However, as a skilled teacher in inquiry, I recognized that these students- who have a greater tendency than most classes to be vocal- would need a mathematical inquiry activity to be connected to their interests. As a result, I introduced the concept of density through an avenue that captures adolescent's

attention- technology. This technology allowed me to capitalize on the competitiveness of these students by offering the perfect opportunity for a “Show Me” activity that challenged students to make correct predictions.

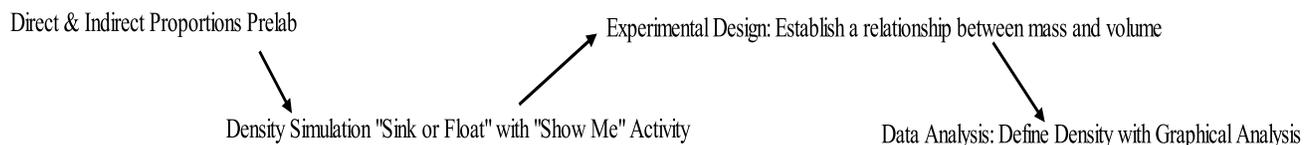
Aside from the age, ethnicity, and ability levels of my students, my classroom comes with its own set of physical dynamics with which to work. The high schools in our school district operate on a 4x4 block schedule. I have these students every day for 100 minutes right after lunch through the end of December. This, in itself, presents its own set of challenges. My students are energized for about the first 15 minutes of class after spending 25 minutes socializing at lunch. However, once their lunch has had time to settle, the majority of them begin to fight sleep. Therefore, I intentionally limit myself to a maximum of 20 minutes of lecture-learning before I begin changing the dynamics of classroom activities. Whether it's taking a kinesthetic break to re-engage their brains or just having them turn in folders, I use different techniques to keep my students both physically and mentally active and focused. I have found that inquiry- whether in a formal or informal lab setting- is an effective method for knowledge retention and kinesthetic learning (**Standards 5 & 6**). For this inquiry lesson, lab availability and technology have significant impacts on the lesson's design. I share my lab with two other teachers, and we use the lab at least once a week. My inquiry designs, therefore, usually have to fit within one 100 minute class session. Consequently, in order to make efficient use of time, the initial investigation into density occurs in a whole class setting using a PhET simulation.

Planning

As an accomplished chemistry teacher, I design lessons that immerse students in chemistry objectives and at the same time cultivate knowledge of science's big ideas. This one investigation challenges my students to delve deeper into their conceptual understanding of

density by using scientific reasoning skills and incorporates important STEM content.

Specifically, I designed this unit so students would derive the equation for density by creating an investigation allowing them to connect previously developed knowledge of mathematical proportions to their experiment. These learning goals are important for my students because as they achieve the goals, they are *developing the mental operations that are essential to advancing the strong content knowledge in chemistry* they will need later as they investigate more complicated equations like the gas laws. Even more importantly, these learning goals *develop in the students mental habits that advance their scientific literacy* and will prepare students like Austin, Tyler, and Rae for upper level courses like physics (**Standard VII**). The image below illustrates the flow of the 100 minute inquiry investigation as we accomplished the content, attitude, and skill goals of this lesson.



Ironically, for the past three years, I have noticed that my students are consistently weak in their ability to reason in science, and students begin to recognize this weakness after they take their first ACT in which an entire portion of the test is designated for science reasoning. The majority of the time, this topic quickly becomes the great equalizer between all my students. The state curriculum for introductory chemistry and the NSS place great value on the students' ability to logically think about science. Consequently, improving my students' ability to analyze experimental data is a long term goal for my course. I achieve this goal most often in two ways- incorporating ACT "Science Reasoning" prep into my bell ringers and using graphical analysis to teach concepts. In this density inquiry, my students experienced first-hand experimental design and graphical analysis. They worked with proportions and equations while improving

their data analysis skills. All of these are essential to the science reasoning process; however, I found that these students had never been asked to use and apply these skills in a lab process. By engaging in inquiry alongside using these skills, they developed a deeper understanding of science reasoning and began building a confidence in their reasoning ability.

Another prominent investigational goal was providing a deeper math and science connection. One common problem I have to combat in my class is the “second math class” syndrome. For my math and chemistry students, it feels as if they are sitting in a second math class at times. This density inquiry lesson is designed to combat that feeling by awakening my students’ natural curiosity and thus creating a greater interest in science and its connection to math. As a result, I modified a standard density lab into an investigation hoping to provide an opportunity for visual and kinesthetic learners to engage in science and form deep connections concerning the relationship between mass and volume. Also, by deriving the density equation for themselves, I hoped they would answer one of their most popular questions- “Where do they come up with these equations?!”

In the video segments of the density investigation, you will see me first model the inquiry process when I pique their interest in density. I help them ask relevant questions, formulate hypotheses, and observe phenomena throughout the process. Recognizing that this opportunity was the first my students had in active independent inquiry, I incorporated the use of technology- a PhET simulation- to both create initial interest and to model inquiry before the students embarked on their own. The class then moved into a guided inquiry process where they designed their **own** investigation into the density properties, thus illustrating the idea that scientists often vary in they how approach a problem. During this process, they established methods for observing mass and volume and chose their data analysis solution. Finally, the

students applied their data analysis methods and defined a density equation, resulting in the final inquiry process of interpreting data and reaching tentative conclusions (**Standard VII**).

Video Recording Analysis

Inquiry investigations can initially be frustrating for students. Because of this, I incorporated four pedagogical techniques to combat this frustration: 1.) I activated prior knowledge. 2.) I established practical life applications for engaging in inquiry. 3.) I provided a clear purpose for the investigation. 4.) I modeled inquiry behavior during a class discussion. The first technique was implemented just before the video begins. My students and I discussed math proportions and their graphical representations for 10 minutes which allowed me to activate their prior knowledge and to set-up proportions as a tool for future use. The final 3 techniques are revealed throughout the first segment of video. Early in the segment, I establish a practical reason for engaging in this particular type of lab design- ACT prep. Due to the range of ages, all of these students will take the ACT, a college admittance exam, at least once in this school year. Over the years, my students have expressed concern about their science reasoning performance on the ACT. By connecting this investigation to improving their science reasoning skills, I supported inquiry from the beginning by providing my students with practical motivation to work through the frustrations that would inherently come with an inquiry investigation.

The video segment opens as I employ my third tool for supporting inquiry- provide a clear purpose for the inquiry investigation. For my students, I relay it to them as the question for the day, “What are the two components that determine density and how are they related?” From there, I begin to utilize my final pedagogical tool which supports the inquiry process- modeling the inquiry process through whole class discussion concerning a PhET density simulation. The simulation provided my students with a tangible, interesting instructional strategy that allowed

me to effortlessly spark the conceptualization of primary inquiry questions. For instance, I first model how to make observations within the simulation with statements like, “let’s play around with the simulation and see what it can do. . . [we can] change the mass, change the volume, and change the type of objects.” By establishing these significant traits, I prodded the thought processes of my students leading them into further investigation with the “Show Me” activity. Therefore, when they were asked to use their own observation skills or “gut instincts” as to whether the wooden cube would sink or float, I had already supported their inquiry observations skills through earlier guidance. Consequently, when Demarkus asks “How heavy is aluminum?” in the next example and then Spencer asks “Is it solid or liquid?” both demonstrate an active extension of the inquiry questions I had previously modeled.

Later, we practiced inquiry investigation as a class by predicting what an unknown box would do in the water. Before we dropped the first unknown box in water, I asked them “Why do you think it will float?” or “Why do you think it will sink?” Interestingly enough, both Vance and Tyler provide the same explanation for different answers- “Because it’s little.” Encouraging advanced thinking with the question “Why?” allowed my students to connect the need for data-like measured mass- within an inquiry investigation to our ability to confirm observations. When I finally propose that “Mass affects density,” I strengthen their ability to design a density equation investigation by linking mass to density. Taking our class investigation further by comparing boxes of different sizes or volumes allowed students to participate in the cyclical nature of inquiry revolving around the manipulation of variables (**Standard VII**). Establishing volume as a final defining characteristic of density ended our class inquiry investigation of asking relevant questions, formulating hypotheses, and observing phenomena and spurred my students to delve into their own investigations concerning volume, mass, and density.

The second segment of video shows me interacting with 4 different sets of lab partners as they design their experiment and establish how they would collect data. Because the inquiry process is more difficult than standard labs, I personally paired my students with diverse skill levels to insure that each partnership had complimentary mixed ability. From past experience, two high achieving students engaged together in inquiry often leads to arguments and accomplishes little, and two low achieving students engaged in inquiry often become overwhelmed and frustrated also accomplishing very little. In this segment, my students are engaged in guided inquiry. I supported inquiry without hindering the process by strategically pairing lab partners, restating questions, preventing students from unnecessary tangents, and supporting the students' verbal thought processes. My specific actions in setting parameters for the materials avoided unnecessary student frustration associated with too much decision making. The students had the supply choices in front of them as they designed their inquiry investigation. My pre-lab selections allowed the focus to be on inquiry rather than on distractions.

In segment 2, I first guided student inquiry by restating their questions and statements- as seen in the 1st and 3rd set of lab partners. The 1st set of lab partners in the video had difficulty completing their experimental design because they could not establish an initial direction for their lab. Keshawn, the student in the gray shirt, had not written down the 3 questions I had given them to start their inquiry. He asked me to clarify the 2nd question; I provided the question, "What materials are you going to use?" as a step toward inquiry and experimental design. By not making the choice for them, I challenged them to ask questions about mass and volume and to decide the experiment's design. Because this lab was their first inquiry lab, the question appeared too vague. Consequently, I led them to consider what they would pick up when they entered the lab. This reworded question was effective because Keshawn immediately began

writing ideas down thus pushing the experiment forward. They still had to consider the materials- water, aluminum, and iron- and how they would collect their mass and volume.

I also encouraged the 3rd set of lab partners' thought process without detracting from their inquiry process. They began with "We're confused." First, I restated their previous decision, "You have your substance, and you have your instruments." Since it was obvious they had not yet considered how to collect data for the substance's mass, I led them through that decision, and then attempted to connect their experimental design to a more familiar activity from class. I did this by restating the inquiry question and relating it to the sequential nature of lab reports. From there, Samantha applied this to their investigation by comparing volume and mass. She demonstrated this jump when she went from "How do we do this?" to asking about the logistics of using a graduated cylinder. Along the way, she recognized she needed to investigate volume and defined how to do that in the lab. Once again, I supported inquiry not by giving a step-by-step procedure but instead by restating and rewording directions giving them a chance to move forward by themselves. This technique guided their thought process without stifling the inquiry process.

For the 2nd set of lab partners, I simply needed to prevent them from chasing an unnecessary tangent. Dominick and Austin had chosen their materials and were actively considering how to obtain data for mass and volume. They had already gone beyond the "What do we have?" and into the "How are we going to use it?" The students had chosen aluminum foil as one of their materials to use to investigate mass and volume but were having trouble with the logistics of measuring the volume of aluminum foil. They demonstrated their understanding of volume when Austin asks, "Does aluminum foil have a height?" These students were already engaged in experimental design and inquiry. I simply offered support in how to measure the height of

aluminum foil. By answering a small logistics question, I helped them continue with their investigation of the materials and prevented them from becoming distracted by a small detail.

The final set of lab partners, Stephan and Kevyn, had chosen their object to manipulate but were confused as to measuring its volume and mass. In this interaction, I simply supported their verbal thought process. As I led them through the logistical process, they caught on quickly. Stephan demonstrates his engagement in observation and questioning when he asks, “Could we use salt instead?” As we talked through the logistics of calculating and manipulating the mass and volume of water, he recognized a foreseen difficulty with water and opted to use another material. At the same time, Kevyn revealed a misconception concerning this inquiry lab. She understood the investigation of density by measuring mass and volume, but she wanted to add the salt and water together. As I reword her statement, Stephan recognizes the issue and reveals his understanding of the investigation when he corrects her saying, “No, you only use one.”

Throughout my interactions with these 4 partnerships and even with my interactions with the rest of the class, I supported their inquiry process of collecting data by restating their questions and ideas. In all 4 instances, I answered only logistical questions –“How would we measure aluminum foil?” “How would we measure the volume of water?” As a result, the students’ inquiry process was supported by my answers while still being guided forward.

In the 3rd and last segment, Stephan and Kevyn analyzed the data they’d collected, attempting to define density. I support their analytical inquiry process by linking their data to their pre-lab and their prior knowledge. As Kevyn begins to analyze her data, her solution was to add her mass and volume numbers together. Consequently, I attempted to nudge them in the right direction by telling them that “I am looking for a trend.” We had discussed trends in our pre lab. By just using the term “trend” instead of giving a mathematical connection, Stephan immediately

identifies a trend- “it’s increasing.” To reiterate this point for Kevyn, I led her to **compare** mass and volume, “If you increase volume what happens to your mass?” As she begins to understand this trend, Stephan makes the leap to data analysis- if they both increase a direct proportion must exist thus demonstrating his understanding of math’s connection to science. Throughout this process, I strived to pose questions that would allow them to draw conclusions. At no point, do I simply tell them an answer. As a result, they were able draw accurate conclusions and analyze data while engaging in the inquiry process.

Finally, I moved them from data analysis into graphical analysis, supporting their developing science reasoning skills. I asked, “How else could you confirm that conclusion? Is there a way to see the relationship other than looking at the table?” Because we had previously discussed proportion graphs and engaged in a graph pre-lab, Kevyn revealed her growing adeptness at science reasoning by immediately proclaiming, “Graph It!” Because my first technique to support inquiry activated their prior knowledge, they had all the mental resources they needed to analyze their data and to conclude that density is mass divided by volume. As a result, Kevyn and Stephan clearly illustrate the mastery of the learning goals of *deriving a density equation, deepening scientific reasoning skills, and establishing the connection between math and science.*

My students quickly began to demonstrate their developing inquiry skills in the 1st segment when Vance, the student in the orange, asked if the cube was aluminum foil or just aluminum before he chose whether the cube would sink or not. Before this, students were only answering “yes” or “no” questions and had not yet verbalized their thought processes to reveal inquiry participation. Later, Vance takes inquiry deeper by asking why humans float in water in response to our “Mass affects density” conclusion. These questions illustrated an active connection to his prior knowledge of the real world and of the scientific concept we were

discussing. They also allowed me to make an interesting real world connection by relating density to “swimming” in the Dead Sea in Israel. As a result, he participated in inquiry as he began to ask questions about what makes the aluminum cube sink and what makes humans float. By engaging students in a whole-class inquiry investigation in which I both modeled inquiry observation thoughts and challenged my students to push their thinking further, Vance had the opportunity to develop the inquiry skills of asking relevant questions and observing because I activated a natural curiosity.

In this 1st segment of video, I promoted student learning and inquiry by providing my students with a tangible, interesting instructional strategy that sparked the conceptualization of primary inquiry questions via the PhET density simulation. My students were engaged in the entire inquiry process from observing to questioning to collecting data and finally to drawing conclusions. My students were then challenged to design their own experiment that investigated mass, volume, and density- their relationship and any mathematical equation that arose. Through the use of Vernier’s Logger Pro software, students, like Stephan and Kevyn, easily entered their data into the program, and it immediately produced a graph for them. By having them participate in computer based learning, I cut down on the needless distractions of remembering how to graph and determining a scale for the axes. Therefore, Kevyn and Stephan were able to quickly analyze their data while the purpose for graphing was fresh in their minds. The technology thereby prevented them from embarking on the other mathematical tangents that Kevyn was leaning towards and promoted student learning and inquiry.

As we move into investigating density together as a class, I opted to use the activity “Show Me” to ensure greater class participation. My students enjoy the white boards, so it offers an opportunity to awaken my students’ brains. It also gives me the opportunity to have my timid

students (like the male student in the front in the white hoodie) actively participate in a classroom discussion. The “Show Me” activity gives every student regardless of their skill level the opportunity to consider their answer before seeing someone else’s answer. I am also blessed to have access to an electronic notepad that allows me to walk through my classroom while teaching or lecturing. The notepad gives me the freedom to stand next my weaker students while teaching concepts. My timid kids love the notepad because they can whisper questions to me that they would never ask if I did not move throughout the room. Both examples demonstrate equity and access for students of all abilities by ensuring equal participation in whole class discussion. In lab activities, as previously mentioned, pairing my students with differing compatible abilities ensures that students of all ability levels have a fair opportunity for success.

Reflection

With the goals of stimulating scientific curiosity, improving science reasoning, and establishing a connection between math and science in mind as I review the video recording, 3 distinct parts of the experiment proved to be effective. The PhET simulation alongside the “Show Me” activity delved into my students’ curiosity in science. The experimental design and data analysis helped deepen students’ understanding of science reasoning and graphical analysis. In fact, later in the semester, I had students come to me after the ACT was given excited because they had used the graphical analysis multiple times throughout the test.

For this class, the density simulation and the “Show Me” activity proved particularly efficient in engaging my students. Erin, the student in the white hoodie, often tries his best to not make eye contact and not participate in class discussions. However, he participated in every “Sink or Float” situation. This class also has a hard time listening to lab introductions. Stephan and

Austin often find themselves confused because they zone out. This activity kept them both engaged, and when it came time for experimental design, they were ready.

The high-medium pairing of lab partners also worked extremely well. Some shy students, like Keshaun, had to step up and lead their groups. While some outgoing students, like Samantha, who coast on others' lead had to become leaders themselves. As far as the goals concerning science reasoning and the connection to math, the experimental design and data analysis sections provided flawless development of these 2 goals. This provided the opportunity to highlight the need for graphical analysis and allowed me to model through science reasoning with students like Stephan and Kevyn. Afterwards, we were able to easily connect how scientists derived the density equation.

I love trying new techniques in my class. Even when they meet my learning goals, I take time to reflect. Because this density inquiry lab was my first trial, I have a list of items that I would modify for future classes. I was quickly reminded how poor students' listening skills really are. Consequently, in the future, I will provide students with a handout that contains the 3 parameter questions to use with their initial inquiry set-up. I also noticed that they were distracted by certain terms. For example, using the prompt, "illustrate the relationship between mass and volume" had some kids drawing pictures during segment 2 instead of designing a lab.

Overall this inquiry lab turned out to be a huge success. In the days since the inquiry lab, a greater percentage of my students understand and remember the direct proportion and indirect proportion graphs- a feat I was never able to achieve with previous classes. As an extension to this inquiry lab, I would love to have my students perform their same experimental design on another object and then graph both sets of data on the same graph. As a result, we could enter into a discussion about calculating density as the slope on the graphs.