Cumulative Summary of Nanoscience Content

Driving Question and Nanoscience

Our driving question is: "How could nanoscience affect the quality of our drinking water?" Our driving question relates to nanoscience because it incorporates the six major concepts of nanoscience, as seen below, and because it forces the students to find a solution to this problem that uses some form of nanotechnology. Furthermore, since many impurities in our water supplies are at the atomic, nano or microscales, nanoscience will be important in helping students to understand just how small this scale is, how we can visualize it, and what properties we can utilize to reach our goal of water purification.

Concepts of Nanoscience

<u>Size and Scale</u>

- *What is it?* - Size and scale looks at comparisons between the different worlds, including the macro, micro, nano and atomic worlds and comparing the sizes associated with these scales. The nanoscale is from roughly 100 nm to 1 nm. Scaling allows one to determine how an object of any size fits into the other scales, whether larger or smaller.
- *Relation to Workshop* – In the Nanometer activity, we used size and scale to assign an every day object as a nanometer and develop a scale to determine what a meter would be. This allowed us to see how small a nanometer actually is.
- *Relation to Speaker* – Andrew Wei's presentation helped solidify size and scale because you could visualize a cell, which we know is very small, and then see how much smaller the labeled gold nanoparticles were within that cell.
- *Relation to Other Concepts* – The size and scale concept is related to the concept of models because sometimes it is hard to visualize objects at such a small size, so we are able to scale them up to understand the true tininess and size of these objects.
- *Relation to Nanoscience* – This concept is related to nanoscience because the processes in nanoscience occur at such a small size range (1-100 nm).
- *Relation to Driving Question* – This concept relates to our driving question because students will want to consider the actual size of impurities in drinking water, because most ions and some compounds found in drinking water are in the atomic- to nano- scales.
- *Examples of Activities for this Concept* –
    - How Big Is It?: Students match images of different items to their relative scale on a size timeline.
    - Nanometer Activity: Students choose an ordinary object to represent a nanometer and calculate how large a meter would be in real life on that scale.

    - These activities will give students a good understanding of how small a nanometer actually is and the scale at which nanoscience researchers are working with.
- *Misconceptions* – The major misconceptions would be that students just do not fully realize how small the nanoscale actually is, and that some students may not understand that most atoms are actually smaller than the nanoscale. Utilizing the activities above will be a good way to curb any student misconceptions with the idea of size and scale.

<u>Surface-Area-to-Volume Ratio</u>

- *What is it?* – SA/V ratio is a comparison of the surface area of an object to its volume. Typically, as you break an object down into smaller pieces, the SA/V ratio for the object increases because the SA increases while the volume stays the same.
- *Relation to Workshop* – A relation of the SA/V ratio to a workshop would be the dissolution of granulated vs. cubed sugar in water. The granulated sugar dissolved faster because it had a larger SA/V ratio compared to the sugar cube.
- *Relation to Speaker* – This relates to the presentation by Ali Shakouri because he mentioned how an ant is capable of holding several times more weight than its body mass due to its SA/V ratio.
- *Relation to Other Concepts* – The SA/V ratio relates to the concept of size-dependent properties because as particles get smaller and smaller, having a larger SA/V ratio, the properties of the substance tends to change.
- *Relation to Nanoscience* – SA/V ratio relates to nanoscience because at the nanoscale, processes occur more efficiently when there is a larger SA/V ratio. Also, the SA/V ratio is affected because of the smaller size of the particles, which increases the SA/V ratio.
- *Relation to Driving Question*: Because students will be looking at water purification, having smaller particles to absorb contaminants vs. one large filter may help absorb a larger amount of contaminants due to the larger SA/V ratio.
- *Examples of Activities for this Concept* –
    - Dissolving granulated sugar vs. sugar cubes in water
    - Looking at how surface area affects the reaction between potatoes and catalase when exposed to hydrogen peroxide.
    - These activities will demonstrate to students that the larger the SA/V ratio, the faster a reaction will occur.
- *Misconceptions* – The main misconception that students may have with this topic is that it is *always* better to have a larger SA/V ratio, which is not the case. To help address this misconception, I would ask students to think about ice cubes melting and how having larger ice cubes will prevent the ice from melting as fast.

Forces (Electrostatic vs. Gravitational)

- *What is it?* – Electrostatic forces are the forces of attraction between charged particles. Gravitational forces are the forces of attraction between particles with mass. At the nanoscale, the mass of particles is negligent, so electrostatic forces are the driving force of attraction at that scale.
- *Relation to Workshop* – In the workshop, we calculated the electrostatic and gravitational forces between an electron and proton at a distance of 0.5 nm. This showed us that the electrostatic forces were much larger than the gravitational forces at such a small scale.
- *Relation to Speaker* – In Ali Shakouri's lecture, he mentioned that there are four major forces, which are electrostatic, strong, weak and gravitational, but that electrostatic dominate at the nanoscale.
- *Relation to Other Concepts* – This concept is related to self-assembly because the particles are more readily going to self-assemble if there are opposite charges to attract to, which would relate to electrostatic forces.
- *Relation to Nanoscience* – The concept of forces is crucial to nanoscience because at such a small scale, electrostatic forces are the driving force of attraction. Therefore, scientists need to take into extreme consideration the electrostatic forces and how they change at this scale.
- *Relation to Driving Question* – Forces relate to our driving question because students will need to consider how the electrostatic forces between their proposed solutions with nanotechnology will interact with the contaminants found in drinking water.
- *Examples of Activities for this Concept* –
    - Calculating electrostatic forces vs. gravitational forces for objects at different scales.
    - This will show students how gravitational or electrostatic forces are more important at different size scales.
- *Misconceptions* – Students will have misconceptions about which forces dominate at different sizes and why. Using the above activity will really help guide them into seeing which forces are important at different sizes and why that is by solving the calculations.

<u>Size-dependent Properties</u>

- *What are they?* – Size-dependent properties are properties of an object that can change as the size of an object changes. At the nanoscale, many common properties, such as color, change drastically. Gold nanoparticles can be blue or red in color rather than the traditional gold color we all know at the macroscale.
- *Relation to Workshop* – An example where we saw this concept would be in the sunscreen activity. Here, we saw that a sunscreen with nanoparticles was almost transparent in color while sunscreen without nano-sized particles of zinc oxide was thick and white.
- *Relation to Speaker* – Ali Shakouri brought up in his presentation that solutions of gold nanoparticles can be red or blue in color and that it is due to quantum mechanics.

- *Relation to other Concepts* – This concept relates to the concept of size and scale because as you decrease the size of objects, the properties change. Furthermore, this concept relates to surface-area-to-volume ratios because as the SA/V is changing, the properties are ultimately changing too.
- *Relation to Nanoscience* – Since these are properties that depend on size, this relates to nanoscience very well because these properties typically change drastically as you get into the nanoscale.
- *Relation to Driving Question* – Students will need to consider how the properties of their filters will be different at such a small scale and how nano-contaminants in water may differ compared to those at the macroscale.
- *Examples of Activities for this Concept* –
    - Comparing a sunscreen that contains zinc oxide nanoparticles to one that does not.
    - This is a good activity for this concept because students can see how the color changes when nanoparticles are used as well as thickness.
- *Misconceptions* – Students will have the misconception that properties, like color, that are taught to be considered intensive, meaning the same regardless of size, could differ at a nano-scale. To curb this, I will use the sunscreen activity to help students visualize this. Furthermore, I will find videos or articles that help simplify the quantum mechanics behind the issue.

<u>Models</u>

- *What are they?* – Models are a way that we can visualize the unseen or hard to see. These can be models for things at the nanoscale, or even things at the macroscale in which they're too large to fully grasp specific concepts (ie- the solar system).
- *Relation to Workshop* – An example of models we used in the workshop would be the blackbox activity. This activity helped to model how atomic force microscopy worked and how we can "visualize" the surface of substances at the nanoscale.
- *Relation to Speaker* – Ali Shakouri spoke a lot about AFM and how we can only "see" the surface of a substance through electronic signals. Therefore, we are really only modeling what the surface looks like based off the readings and data we get, and that that model could differ depending on the instrument we use.
- *Relation to Concepts:* The concept of models is related directly to size and scale because models help us visualize at a manageable working level objects that are either too large or too small.
- *Relation to Nanoscience:* Models are used in nanoscience to show us what is happening at the nanoscale because it is too hard to see with the naked or even aided eye.
- *Relation to Driving Question:* This concept relates to our driving question because students will have to create models of their solution to the problem in the driving question to represent what cannot necessarily be visualized.
- *Examples of Activities for this Concept:*

    - The Black Box Activity is a perfect activity to showcase this topic because it depicts how AFM works, but on a macroscale, so it is easy to visualize.
- *Misconceptions* – Students will have the misconception that all models are perfectly accurate. I will need to show students that all models have limitations and that they cannot possibly portray every aspect of what is being modeled perfectly. Limitations simply will exist, and that can even be demonstrated with the black box activity.

Self-Assembly

- *What is it?* – Self-assembly is the process in which substances come together to form a unified structure without help while keeping their original characteristics. Factors that aid in self-assembly include charges, temperature and shape.
- *Relation to Workshop* – Self-assembly was portrayed neatly in the simulation activity we completed because it showcased all the different factors that affected self-assembly and allowed us to create patterns for self-assembly while utilizing the different factors.
- *Relation to Speaker* – Ali Shakouri talked about how DNA is a self-assembly process when the DNA double helix forms because the base pairs are organized such that they create hydrogen bonds with each other to facilitate the helix formation.
- *Relation to Concepts* – Self-assembly relates to electrostatic forces because charges on molecules are a large driving factor in self-assembly.
- *Relation to Nanoscience* – A lot of the nanoscience process involves ways of having molecules self-assemble to form the molecules and shapes for the nanoscience research at hand (formation of carbon nanotubes, etc.)
- *Relation to Driving Question* – In order to create purification methods with nanotechnology, students can develop nanoparticles that can self-assemble with water contaminants to easily remove them from the water, utilizing the several factors listed above.
- *Examples of Activities for this Concept*:
    - Allowing students to do the Gummy Capsules activity will give them a sense of self-assembly because they can see how different factors affect the formation of the "self-assembled" capsules. Since this is just a model, it can also be tied in to the models concept.
- *Misconceptions* – Students may have the misconception that chemical reactions, such as synthesis reactions, are examples of self-assembly. To curb these thoughts, it would be ideal to have them see that the properties of the reactants are different than that of the products and that the chemical reactions do not always move towards a state of more order.

Remaining Questions:

- Since nanotechnology is a big focus of our projects, what are some good resources to get students intrigued and excited about the idea of nanoscience so that we're not just requiring it of them, but instead we have engaging ways of getting them to want to explore nanotechnology?

References:

Madsen, A. (2015, June). *Nanoscience Lab Activities*.

Shakouri, A. (2015, June 8). *Overview of Nanotechnology* [Powerpoint Slides].

Wei, A. (2015, June 9). *Nanomedicine: Science or Science Fiction?* [Powerpoint Slides].