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Cumulative summary of Nanoscience Content

In the nanoscience portion of the class we focused on a few main ideas in the field. The first that we addressed was the idea of size and scale. This was followed by the importance of the surface area to volume ratios. After that we discussed the properties associated with forces and which forces apply at different scales. Models were discussed as a way to address misconceptions and give a better understanding of the concept. The last two concepts covered were the affect of size dependent (extensive) properties and finally the idea of self assembly.

Due to the infinitesimally small nature of nanoparticles, students often have trouble with understanding what the nanoscale really is. This is similar to the struggles associated with time when evolution is taught in biology courses. In this, we did activities relating objects that we can see to other macro objects but scaling them as our object as 1 nm and the other objects on a "macro" scale in comparison. This allows students to rationalize the the ratio of nano particles to macro scale particles and also allows students to think about real world examples they can see and are more familiar with. One speaker that addressed this was Ali Shakouri who discussed not only the small scale, but also some of the benefits of working at that small scale including the efficiency of the length scale. One way to teach this in to have students organize objects by size or have them create their own scale, similar to how we did.

One of the major driving forces of changing properties at the nanoscale is the surface area to volume ratio. One example is with gold nanoparticles. As surface area increases in comparison to volume, gold will change from a non reactive metal to a reactive metal. With more area exposed to react, the particle is more likely to react to other particles. This is due in part to the electrostatic potential being spread over a smaller volume. Other properties than electrostatic potential can change greatly, particularly if they are tied to either surface area and volume. One lab that showed this by showing how smaller particles, granular sugar, will dissolve faster than the larger particle, the sugar cube. One speaker that addressed this was Ali Shakouri who discussed this in relation to the "strength" of an ant and how part of heir ability to lift things that were so much bigger than them was in relation to the surface area and volume of their muscles and if they were the size of humans, they would have the same constraints. One misconception that may come up in this unit is that a large surface area to volume ratio is always better, which is not the case. One way to address this misconception this is with large and small ice and showing large ice is better because it will last longer. One way to teach this concept is through demonstration, using agar cubes of different sizes can show how diffusion occurs faster in smaller cells (smaller surface area to volume).

Gravitational forces are the force that most students will be most familiar with, so the idea that other forces might be stronger will be a misconception that will need to be addressed. Electrostatic forces are stronger than gravitational forces at he nano level because gravitational forces are dependent on mass and the masses at the nano level as so small, and smaller in comparison to the charges on the particles as well. We did this in the lab by physically doing the calculations for both coulomb's equation and the gravitational equation for a proton and an electron. This is actually probably the most effective way to demonstrate this concept and how I would teach this in my classroom. The speaker that discussed this most was professor Shakouri who told us that the EM fords tend to dominate at the nanoscale. One way to address this misconception is to have the students calculate the the values for both the gravitational and electrostatic forces on the particles so the students can see the values for each.

Models are used to give an overview of a topic and allow students to better understand a certain topic. Models are often used to show things that would otherwise be inaccessible to students of researchers. One way this is often done is through simulations or electronic visualizations. This is particularly helpful in nanoscience because it allows us to see things on the nano level. One way we talked about this was when the speaker Ali Shakuri Discussed the scanning probe microscopes and atomic force microscopes which can provide a 3d illustration on a screen of the nano material. We learned how this tool was used by doing the blackbox activity where we stuck a "probe" into holes in a shoe box to determine the object within. Another way to teach this is by having students do simulations like we did with the the self assembly situation. The gummy activity would also work as a teaching tool because it demonstrates self assembly even though it is not technically self assembly.

Size dependent properties are related to why properties change at the molecular/nano levels. One way this is done is by attaching nanoparticles with hydrophobic and hydrophilic portions to different particle to change the properties of the original substance. This came up in the lab with the lotus affect both with the broccoli, kale and lettuce as well as the t-shirt. This was brought up by doctor Alex Wei when he discussed attaching particles to nanoparticles so that the will better attach to cells for more precise form of cancer treatment. This can be taught is through a mess about activity where they can explore different properties that change with scale. Having multiple activities the students can do at their own pace is the best case scenario.

Self-assembly happens most often in biology. Self assembly occurs, for example, in DNA where the nucleotide will arrange themselves so that the nitrogen bases are hydrogen bonded to one another, specifically the adenine will bond to thymine and guanine will bond with cytosine. There are no little machines that come in and make this happens, it happens naturally. We observed how this happened through a simulation activity that allowed us to manipulate different properties about particles and watch how they arranged themselves. This is used in nanoscience by attaching things to nanoparticles so that you can take advantage of this naturally occurring phenomenon. The speaker that addressed this best was Ali Shakuri who discussed how this all related to biomolecules in particular. Peter Bermel also discussed this in regards to butterfly wings and peacock feathers colors being a result of self assembly at the nano level. Students often fail to realize that this is a naturally occurring process, often students will try to personify the particles and saying they are actively "thinking" about what they are doing, where in actuality, properties like hydrophilic and hydrophobic are dictating the interactions. The gummy lab we did would serve as a good way to address these misconceptions because it shows that the environment or solution can dictate the self assembly and just having the particles together is not enough to make them come together. I would use this lab because it is a nice visual, but also aft activity for the students to get them excited about the material.

Several of these concepts are interrelated. The most prominent example is with size and surface area, because as we decrease the size of the particles, it is impossible shrink the particles down to any size without also impacting the surface area to volume ratio.   This is also connected to ideas of force because gravitational forces are dictated by mass rather than change, so as the particles get smaller, so does their mass and subsequently the affect of gravitational forces. Likewise, having a larger surface area allows for attaching different particles and changing properties at the nanoscale.

The driving question for our unit was "how could nanoscience affect the quality of our drinking water". This ties in a few different concepts that we have talked about. Forces are pretty directly tied in because filters can use a number of different ways to filter out particles. If we are filtering out nanoparticles, electrostatic interactions would be the best way to filter out the particles. Another idea that can be addressed is size and scale because students need to consider the size of the particles in designing your filter, because if the size of the holes in filter is too large, it will not fill out the desired particles. Size dependent properties can be used as a way to filter out particles based on properties. Similarly, size dependent properties can bee used to attach to the particles and the filter them out using properties like intermolecular forces. Another topic that relates to this theme is surface area to volume ratios. By maximizing surface area, students should be able to remove more particles.

One question I still have about nanoscience is what drawbacks man made nanoparticles have on humans. While we have talked about some drawbacks of nano, but I feel I don't have a full understanding of all the drawbacks.

Resources:

The big ideas in nanoscale science and engineering. Stevens, et al.
Presentation by Ali Shakuri
Presentation by Alex Wei
Presentation by Peter Bermel
Labs designed by Alex Madsen