

## **Nanoscience from the beginning: Getting geoscientists to think differently as freshman**

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At Virginia Tech, a freshman geoscience major can also take a freshman-level course called “Introduction to Nanoscience”. In fact, this is the first class in one of only two undergraduate nanoscience majors in the United States. The nano major is about a “science without boundaries”, a wonderful blend of physics, chemistry, biology, and math all rolled into one discipline without tall silos. Besides a year of introductory nanoscience, some of the other courses in the nano major include the quantum physics of nanostructures, nanoscale synthesis and characterization, and environmental nanoscience. From the beginning, students are taught something that is a fundamental truth, including in how the Earth works: the properties and behavior of materials (including all Earth materials, solid, liquid, and gaseous) do not scale evenly as the material gets smaller and smaller. A piece of gold 1 micron in size will exist and behave dramatically differently from a piece of gold one nanometer in size. This is where Newtonian thinking coverts to quantum behavior, gravity is no longer a relevant force, and everything is about band electronic structure, van der Waals forces, quantized energy levels, and densities of states. As the “weirdness” of quantum mechanics comes into focus, now one realizes through nanoscience that we can look at the atmosphere, hydrosphere, and lithosphere in different and in fact extended ways. There are finally countless new directions to study the Earth in all its “nanoness”, and the opportunities are everywhere and practically endless.

The good news is that more and more Earth and environmental science teachers have been exposed to nanoscience. It helps that participants in the nanoscience revolution are currently producing about 140,000 scholarly publications per year, with funding in the many billions of dollars per year. And like the other great revolutions in science and engineering, the nano-revolution is expected to continue onwards for centuries, always being fundamentally relevant to the way we live, the products we buy, our understanding of this planet, and new revolutions that will depend on it in the future.