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Walt Trybula
Texas State University-San Marcos

Dominick E. Fazarro
Sam Houston State University

Alton Kornegay
North Carolina A&T State University

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Walt Trybula, PhD
Texas State University-San Marcos

Dominick E. Fazarro, PhD
Sam Houston State University

Alton Kornegay, PhD
North Carolina A&T State University

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Abstract

Nanotechnology is an emerging as an important consideration for the workforce, our daily lives, and education. This paper discusses the definition of nanotechnology, it's emergence within today's workforce, the skills needed for workers within the emerging nanotechnology sector, nanotechnology's impact on society, and how this new paradigm is impacting post-secondary education.

Introduction

The Basics of Nanotechnology

The question that is very difficult to find a consistent answer for is “What is NANO?” Generally this term is referred to nanotechnology, which deals with structures with a size of 100 nanometers or smaller. A number of researchers and companies state that the nano region starts at the 100 nanometer (nm) boundary. Is there a reason to provide this boundary as anything more than a talking point? Nanotechnology is entering a new threshold of many possibilities to change the way we see things. The National Science Foundation (NSF) projects that, there will be two million workers by the year 2015 (Toon, 2006). Toon also stressed that 80% of the people surveyed by the Project on Emerging Nanotechnologies indicated that they know little or nothing about the topic. The authors are cognizant of the critical issues which surround the development of a nanotechnology workforce. Therefore, this article will address the implications of nanotechnology in society and what the workforce will look like into the 21st century.

There are objects with dimensions larger than 100nm are commonplace for products developed in industry, such as processor chips and alloys. There are materials larger than 100nm that can pass unimpeded through human skin. Objects that are smaller than 100nm need to be less than 70nm before the dominant force that will hold them to a surface becomes the van der Waals force. The ability of a Gecko to climb walls and walk on ceilings is due to minute hairs attached to small hairs connected to their limbs. The thickness of the final hairs is much less than 100nm and it is the properties of this small size that provide adhesion through the van der Waals force. The properties of gold nanoparticles less than 20nm in size provide the ability to reflect different color, which color is based on the size of the particles. Aluminum nanoparticles become extremely reactive when their size is less than 20nm. There are numerous examples of apparent change in observer properties of particles when their size is very small. This is an intriguing aspect of nano. These apparently new properties provide promise for new applications that will change the world.

To make this discussion clearer we refer to anything smaller than 100nm as NANO. The National Nanotechnology Initiative (NNI) has significant amounts of information on their website. The NNI indicates that nanoscience investigates the property of materials in the 1 nm to 100nm region (NNI, 2008). However, the key statement is that this region is where material properties may be different from those that are familiar to us.

The New Workforce

The skills required for working in nanotechnology depend on the stage of the development of the effort. The NNI the initiative promotes, “ A solid educational foundation, a skilled workforce,…programs continue to be developed … for all levels, including K-12 schools, community colleges, vocational schools, and major research universities” (¶1). The makeup of the new workforce will consist of researchers, technicians, manufacturing engineers, and production workers (NNI, 2009)

The primary skills at this stage of the development require an advanced degree(s) in science, technology, and or biology. As the development of the products move into a production stage, the supporting efforts require more of a technician background, but one with an emphasis on advanced technology. Initial development efforts require an understanding of some of the basic properties of the material being employed and the product or device being developed. There are a number of science, engineering, and technology programs in the U.S. that address the fundamental requirements for nano-technicians. Ideally, programs provide an understanding of the fundamentals of the technology, the handling of the materials, and the manufacturing of products. Educators must create new paradigms of workforce-training programs to give technicians the knowledge and self-assurance to be competitive on the national and international stage.

Each organization will need to provide additional learning opportunities to more fully align the general training with the specifics of the particular applications. However, there is also a requirement to be able to develop an understanding of emerging technologies. In order to manufacture any item, it is necessary to be able to measure the resultant product. Working in the nanometer realm, there are few tools to accurately measure mass produced devices or materials to the accuracy required.

Typically, accuracy measurements required in manufacturing need to be at least one order of magnitude smaller than the item being measured. If we want to produce a part that is accurate to 0.01 inches, we should be able to measure to 0.001 accurately. The reason for this is that if the dimension were to actually be 0.014, the measurement, (if it were only capable of resolving 0.01 inch dimensions), would yield a 0.01 measurement. This could provide issues further in the manufacturing process. The problem with this requirement at the nanometer realm is that the equipment is not available to make these type measurements in a timely manner. In volume production, many measurements are required each hour. Using the best available equipment, it may be possible to get one or two measurements an hour that are accurate to 1nm. New concepts will be developed that will yield new equipment to make these type measurements. The workers will need to be able to learn not only how to use the newly developed equipment, but also how to ensure that it is maintained properly. At this time, we do not know what kind of skills, simply because we are only imagining the scope of the technology required.

A second skill that will be required is an understanding of what the real issues are regarding safety in nanotechnology. Decisions will need to be made in evaluating a safe work condition. Tests must be conducted to see what equipment may be producing dangerous material and the technicians must be able to obtain accurate data on the materials. Adequate procedures must be created for laboratory and manufacturing facility. Priorities must be determined in evaluating each situation. A comprehensive program does not exist to train workers in how to evaluate their situation. There is no directory currently used industry to find the characteristics of the materials. Although the handbook of Physics and Chemistry addresses the properties of materials and their interactions, the handbook does not address the nanomaterial properties. The development of a program to address NANO-SAFETY requires the consideration and evaluation of all the potential known issues and the ability to include other issues as they arise. The program also will require that training programs be put in place to develop the expertise required for handling any nanotechnology issues that arise. This brings us to the topic of this paper, how do we train, how do we educate, and how do we protect our workforce? Without the safety of both people and the environment is critical to establishing a solid presence in nanotechnology.

Impact of Nanotechnology on Society

According to the Project on Emerging Technologies (2005),“The National Science foundation predicts that the global marketplace for goods and services using nanotechnologies will grow to $1 trillion dollars by 2015” (p. 1). A majority of the work is being done is in the health field, with the promise to revolutionize the treatment of many diseases. This new technology will provide many applications that people will experience in everyday life and will eventually improve the quality of life. This is only the start of the developments of future products.

Silver nano particles are being incorporated into wound dressings. The addition of these nanoparticles promotes the healing of wounds. There have been some suggestions that silver nanoparticles that are 12nm will also prevent infection due to their ability to destroy bacteria. The advantage to this approach over antibiotics could be that the silver particles are naturally occurring and consequently the bacteria will have a very difficult time developing immunities to the particles. There is a negative side to this as well. Particles that can impact bacteria and prevent their spread will have that impact whether the bacteria is good bacteria or bad bacteria. Consequently, the Environmental Protection Agency is concerned about the application of silver nanoparticles that have the potential to be released in the environment. Application of technology is neither good nor bad, but the consequences of our actions can have good or bad effects.

Gold nanoparticles are being attached to molecules that have a propensity to attaching themselves to cancer cells. Work done at Rice University by Professor Naomi Hallas and her colleagues is developing cancer treatments based on the ability of the gold particles to absorb infrared light and heat up the material and surrounding area. With the molecule attached to a cancer cell, the heating of the gold will destroy the cancer cells. There are many efforts in the health sciences to examine means of improving treatment of illness by employing various types of nanotechnology.

In addition to being used in applications to health care, Carbon Nanotechnology Tubes (CNTs) are being applied in automotive manufacturing. Toyota is replacing steel bumpers with a composite that includes CNTs. The result of this replacement is that the bumpers are lighter (fuel saving) and eight times stronger (less prone to damage). CNTs are being employed to make sports equipment stronger and lighter. Both tennis and baseball have benefited from the incorporation of CNTs. The tennis racquet incorporating CNTs is both lighter and stronger. Baseball bats benefit with improved strength and lightness. The fact that these items are more expensive is offset by their performance and improved longevity.

While these are some examples, it is very difficult to predict where things will go. This developing technology revolution can, in many ways, be compared to the plastic revolution in its early days. The products went through a long learning curve before incorporation of plastic into the product was accepted in better products. Early in the development of plastics, the term plastic implied an inferior quality. As more and more types of plastic were developed, the quality improved, the application specific properties were developed, and the term plastic was not even employed to describe the product. It would not be unexpected for the various implementations of nanotechnology to go through the same type of development cycle.

There are hundreds of products being developed for the consumer market. The Project on Emerging Nanotechnologies, a Washington D.C. initiative associated with the Woodrow Wilson International Center for Scholars has identified products.

Figure 1. Description of potential applications of nanotechnology produced by the BBC and published electronically. [Compiled by Jo Twist, BBC News On-Line, July 28, 2004]

Figure 1 shows twelve projections for future developments. Each of the numbers is tied to the explanations below.

1. Organic Light Emitting Diodes (OLEDs) for displays
2. Photovoltaic film that converts light into electricity
3. Scratch-proof coated windows that clean themselves with UV
4. Fabrics coated to resist stains and control temperature
5. Intelligent clothing measures pulse and respiration
6. Bucky-tubeframe is light but very strong
7. Hipjoint made from biocompatible materials
8. Nano-particle paint to prevent corrosion
9. Thermo-chromic glass to regulate light
10. Magnetic layers for compact data memory
11. Carbon nanotube fuel cells to power electronics and vehicles
12. Nano-engineered cochlear implant

The point that this figure makes is that there are many applications that people will experience in everyday life. Each of the items can improve the quality of life. This is only the start of the development of future products.

A New Technology Paradigm for Post-Secondary Schools

The education effort requires having an understanding of the technical aspects--not a detailed knowledge of the specific properties, but an understanding of safety precautions. Developments and the increase in the number of nanotechnology products require that we have a workforce to evaluate situations and initiate remedial actions where necessary.

As nanotechnology emerges as the new technology wave of the 21st century, decisions must be made concerning how to proceed to prepare post-secondary schools. Brian Baird, Washington 3rd District Subcommittee Chairperson, stated "Nanotechnology is a tremendously complex field involved in the development of hundreds of products and amounts to billions of dollars in revenue for a variety of companies" (p.1). The U.S. House of Representatives Committee on Science and Technology created a subcommittee on research and science education and an exploratory meeting was held to listen to testimony based on the Nanotechnology in Schools Act. 2436 (2007) to determine the issues regarding how students and the public will be educated about nanotechnology. These were the questions to address the issue (pg.1):

- What unique benefits does access to high-tech equipment generally offer to high school students, undergraduates and community college students, and visitors to informal science centers?
- What science, technology, engineering, and mathematics (STEM) education goals do hands-on opportunities with high-tech equipment fulfill at the secondary school level and at the post-secondary school level? What goals does providing these opportunities meet for the nanotechnology research and business communities?
- What factors need to be considered when bringing high-tech equipment to the classroom?
- What types of educational activities is the Federal Government funding in nanoscale science and engineering under the National Nanotechnology Initiative?
- Is the level of resources available for these activities adequate? Are the priorities for funding appropriate?

The questions mentioned must require out-of-the-box thinking with risk-taking to develop innovative curriculum. Currently in the U.S. public school systems, students are deficient in math and science, which can endanger the growth of a nano-workforce. There is little interest among secondary students to gravitate towards fields which develop and produce high tech goods (Fonash, 2001). According to Fonash (2001),

> The key to increasing awareness is informed school educators and counselors. They must appreciate the role of nanotechnology will have on society, understand what is required to prepare the nanotechnology workforce, and successfully "get the word out" to students and parents (p.1).

Administrators and faculty must be prepared and take the necessary steps to make the transition in a new technology paradigm. To implement a nanotechnology curriculum, a multi-disciplinary approach is a logical solution to assist in identifying target areas that pull in faculty with relevant expertise to develop courses (Sheeparamatti & Kadadevaramath, 2007).

Expanding the knowledge base of grades K-20 in nanotechnology, academic institutions must be proactive in initiating the new age of this technology. The College of Engineering at Penn State University has a partnership with The Pennsylvania Nanofabrication Manufacturing Technology (NMT) to develop a technology incubator for creating knowledge and updating the workforce skill sets for the state. The Center for Biological and Environmental Nanotechnology at Rice University in Texas is focusing on research for developing nanoscience in the "wet/dry" interface. Their activities include observing the interface between nanomaterials and aqueous systems at multiple scales. These institutions and others researching nanotechnology are the catalyst for developing workforce education and development initiatives in the U.S.; however, single institutions alone cannot undertake the nanotechnology challenge which faces this country. The viable solution for succeeding the implementation of nanotechnology is multi-institutional collaboration.

A multi-institutional collaboration must be able to identify goals, objectives, and their role in the effort. Funding will be an important catalyst in executing objectives and work plans to educate a nano-workforce. Workforce preparation will include collaborations between academia and research centers; while industry must commit to mutual partnerships to assist in the education and training of nano-workforce. The Texas State University System universities have collaborated to create the Texas State University System Nanotechnology Task Force. See taskforce model in figure 2.

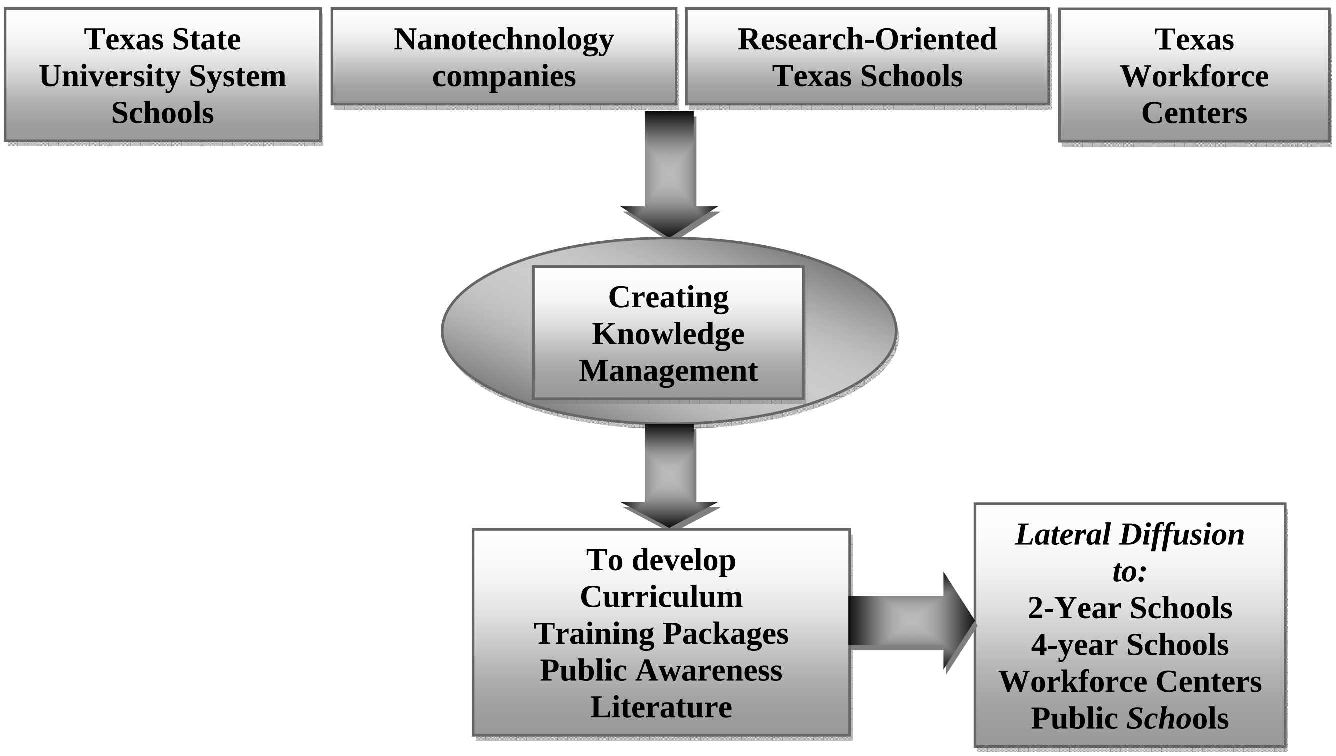

Figure 2. Texas State University System Nanotechnology Task Force collaboration model. From "The Evolution of Nanotechnology Education: Lateral diffusion for the 21st Century Workforce", by Dominick E. Fazarro paper presented at the NanoTx Conference, Dallas TX October 2-3, 2008.

The purpose of the task force is to assist in workforce development of nanotechnology workers in Texas by building partnerships with workforce development centers, and research institutions such as University of Texas, Rice University, and Texas A&M University.
Here are some considerations for initiating a multi-institutional collaboration:

- Identify the strengths for each university
- Establish goals and objectives for the collaboration
- Establish how the collaboration will serve the public
- Establish timelines to achieve objectives

- Develop an action plan to write grants for secure funding

Future Implications

The emergence of a nanotechnology workforce is rapidly approaching, educational institutions, industry, and government must make the necessary preparations for this new technology movement. Industry and academic institutions must collaborate to create the foundation needed to grow a nanotechnology workforce. States like California, Minnesota, North Dakota, New York, Oklahoma, Pennsylvania, Texas and others have created two-year and four-year programs to invigorate the nanotechnology workforce development initiative to prepare for the global introduction of the 21 century workforce. Students must be exposed to state-of-the-art equipment to become cognizant of the future growth for opportunities in the U.S. A well-prepared nano-workforce will be able to deploy new innovative products which will benefit society. However, leaders in education and industry must be proactive to take the necessary steps to build a vibrant nano-workforce to compete globally.

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