

# The Workforce Needs of Nanotechnology Firms: An In-Depth Study of Biotechnology, Microelectronics, and Aerospace Firms in the State of Arizona, USA

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## ABSTRACT

While much effort has been devoted to describing the latest innovations in nanotechnology, relatively little effort has focused on understanding the skill and workforce needs of companies involved with nanotechnology. To help advance a broad understanding of these needs, researchers from the John J. Heldrich Center for Workforce Development<sup>1</sup> at Rutgers, The State University of New Jersey, are completing a study of the effects of nanotechnology on the skill and workforce needs of high technology companies in the state of Arizona, USA.

The Phoenix and Tucson metropolitan regions have a concentration of firms in three high technology industries at the center of nanotechnology development: the biotechnology industry, the microelectronics industry, and the aerospace industry. The study will collect and analyze information through a series of in-depth interviews with nanotechnology firms and with an on-line survey of companies using nanotechnology in the state of Arizona.

**Keywords:** workforce, education, skills, training

## 1 INTRODUCTION

Nanotechnology, defined by the National Science Foundation as “research and technology development at the atomic, molecular or macromolecular levels, in the length of approximately 1 – 100 nanometer range,” [1] is having a significant impact on the workforce and skill needs of high technology companies.

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In order for firms to fully realize the potential of new technologies, they must have a supply of workers with the necessary skills. For example, companies engaged in research and development in nanotechnology must have scientists trained in the behavior of particles at the nanoscale level. The effect of nanotechnology on the workforce and skill needs of companies is not limited to highly educated scientists and researchers. Firms pursuing nanotechnology-related production must also have a sufficiently large and appropriately trained technician workforce to support this production.

A number of specific research questions are suggested when considering workforce preparations to facilitate nanotechnology development. Will the demand for nanotechnology workers outpace the supply of qualified workers? What skills must researchers and scientists possess to take maximum advantage of the commercial potential of nanotechnology? Will the manufacturing of devices, products, and materials using nanotechnology require that production technicians must learn new skills?

There is some evidence that companies involved in nanotechnology are currently concerned about their ability to find qualified workers with the necessary nanotechnology skills. In a 2004 online survey, nearly 50 percent of 720 respondents from the European nanotechnology community reported that European companies would experience a shortage of workers with appropriate nanotechnology training within the next 5 years. An additional 25% of respondents reported that European companies would have a shortage of such workers in 5 to 10 years [2].

In the United States, some experts have predicted that the demand for skilled nanotechnology workers may exceed supply [3]. In addition, other experts have concluded that education and training may be inadequate in many regional markets [4] [5].

Government policy makers have recognized the need to create educational programs to train individuals for jobs in nanotechnology. For example, a primary goal of the National Nanotechnology Initiative (NNI), an effort of the

National Science Foundation, is to ensure that the United States has a supply of qualified workers for nanotechnology-related jobs and that educational institutions implement programs to build this skilled workforce [6]. Through NNI, the US government continues to fund the development of new curricula and programs designed to educate high school and college students about nanotechnology.

## **2 PURPOSE OF THIS STUDY**

Despite previous studies and government efforts, little is known about how nanotechnology is changing the skill and workforce needs of companies. To better understand these issues, the Heldrich Center for Workforce Development at Rutgers University is completing a study of the workforce needs of nanotechnology firms. The five-year study is being conducted with funding from the National Science Foundation as part of the Center for Nanotechnology and Society at Arizona State University.

The first year of the study focuses on the workforce needs of nanotechnology firms in Phoenix and Tucson, Arizona. Southern Arizona is home to significant clusters of biotechnology, microelectronics, and aerospace firms using nanotechnology. By focusing on one region per year, the study is able to explore specific industries on a more in-depth level.

In addition, while this study focuses on one region in depth, the conclusions will be relevant to educational institutions and policymakers in working to ensure that there will be an adequate supply of skilled, qualified workers for the biotechnology, microelectronics and aerospace industries in other regions of the USA and in other countries.

The study results are based on interviews with companies engaged in nanotechnology and on a web-based survey of nanotechnology-related employers and researchers in Arizona. The web-based survey is being used to collect information from high technology companies in Arizona about the effect nanotechnology is having on the skills needed by their employees. The survey results will be used to advise government policymakers and education and training institutions so that they can ensure that there is an adequate supply of skilled workers in Arizona and the nation.

## **3 NANOTECHNOLOGY IN ARIZONA, USA**

Arizona is an active center of nanotechnology in the United States. For example, there are approximately 90 members in the Arizona Nanotechnology Cluster, a nonprofit organization active in promoting cross-industry

cooperation and information sharing among companies involved in nanotechnology research, product development, and assembly.

In addition, the metropolitan regions of southern Arizona (Phoenix and Tucson) contain several industry-based clusters of firms active in nanotechnology research and development. Three of these nanotechnology-related industries—biotechnology, microelectronics, and aerospace—were selected for focus in this project. Each of these industries has a large presence in Arizona and has the potential for extensive work related to nanotechnology.

### **3.1 Biotechnology**

Biotechnology firms engage in a wide variety of life science related activities, including the research, development, and production of pharmaceuticals and medical devices. In the biotechnology industry, nanotechnology can potentially be used to develop devices and process that can be used to diagnose medical conditions and to more effectively treat illnesses [7].

The state's 407 biotechnology firms play an important role in Arizona's economy, employing approximately 5,547 employees and supporting a large number of high-paying research and development jobs [8]. The sector has grown in recent years as well, with 5% annual job growth between 2001 and 2003. The region also has two active industry cluster organizations, one headquartered in Phoenix and one headquartered in Tucson.

### **3.2 Aerospace**

Aerospace firms are involved with developing, producing, and operating aircraft and aircraft support systems for both private sector and military clients. The aerospace industry is a key component of the Arizona economy, employing more than 33,000 workers in 2003 [8]. The number of jobs in the industry remained stable between 2001 and 2003. The concentration of aerospace industry activity in Arizona suggests that nanotechnology developments in this industry will have significant workforce implications for the region.

### **3.3 Microelectronics**

Firms within the microelectronics industry develop and produce electronic components for both commercial and research uses. The industry employs about 27,000 people in Arizona [8]. Although employment in Arizona's microelectronics industry decreased by 31% from 2001 to 2003, there was an increase in industry employment in 2005. Interviews with members of Arizona's nanotechnology community indicate that the current research being conducted in nanoscale electronics is likely to have significant education and training implications for future technician-level workers in the industry.

## 4 PRELIMINARY FINDINGS

Based on a review of the existing research and interviews with key stakeholders within Arizona's nanotechnology community, the authors have identified two preliminary findings. These findings will be further explored through an analysis of web-based survey results and through additional interviews with companies involved in nanotechnology.

### 4.1 Need for Interdisciplinary Skills for Research Scientists

The initial research findings suggest that scientists and researchers working in nanotechnology must possess the skills, knowledge, and abilities to communicate and collaborate with scientists and researchers in other fields.

Interviews with leaders from the nanotechnology-related industry clusters in Arizona indicate that future cross-sector collaborations are likely to be crucial to unlocking new nanotechnology developments. Many of the yet-to-be discovered methods for working with nanotechnology are expected to require several different types of science, and hence will employ workers in different, but related scientific fields.

In addition, in Arizona there is currently a significant amount of cross-sector interaction among firms in the three industries selected for focus in this report. For example, 58% of aerospace firms who responded to a 2005 survey of high technology businesses in Arizona reported that they either buy materials from or sell materials to microelectronics firms in Arizona. In addition, 31% of biotechnology firms reported a business relationship with microelectronics firms, while 13% of biotechnology respondents reported buying from or selling to aerospace firms [8].

Over ninety percent of the 720 responses to a 2004 survey of the European nanotechnology research community reported that interdisciplinary skills were crucial or very important to workers in nanotechnology [2].

In addition, a recent research paper completed by the European Centre for the Development of Vocational Training concluded that interdisciplinary knowledge is the primary professional competency for nanotechnology workers. The authors note nanotechnology developments typically involve the intersection between two or more distinct scientific fields, such as physics, chemistry, biology and specific engineering fields [7]. For example, biologists and physicists must collaborate in the field of biophysics.

### 4.2 Need for all Nanotechnology Workers to be Trained to Address / Minimize Possible Workplace Safety and Health Risks

Nanotechnology, by definition, involves working with materials that are extremely small and are may interact with each other in previously unobserved ways. Governments and researchers are beginning to focus on the possible effect of nanotechnology on the health and safety of workers. The National Institute for Occupational Safety and Health has begun research on the potential health risks to those working with nano-scale particles. Although the extent of the health risks remains unclear, precautionary measures have been recommended, including:

“The use of good work practices, the education and training of workers, and the use of personal protective equipment, when needed, should help reduce the potential for exposure.” [9]

Interviews with nanotechnology stakeholders in Arizona support the conclusion that workers, whether they are researchers/scientists or technicians, must be trained to identify possible health risks and to take the necessary safety precautions. The web-based survey and future interviews with nanotechnology employers will be used to further explore this issue.

## 5 OTHER ISSUES TO EXPLORE

The Heldrich Center is currently analyzing the web-based survey results and conducting additional interviews with companies involved in nanotechnology in Arizona to further explore the effect of nanotechnology on the skill and workforce needs of high technology companies. This ongoing research and analysis will focus on two primary areas.

### 5.1 Skills Required of Scientists and Researchers

In addition to interdisciplinary and safety and health skills, researchers and scientists involved in nanotechnology will need to possess additional skills to effectively conduct research and to develop new materials, devices and products with nanotechnology.

A majority of the 720 individuals involved in the European nanotechnology community who responded to an online questionnaire in 2004 reported that four other skills were crucial or very important for nanotechnology workers. These skills include communication and presentation skills (nearly 70% of respondents), awareness of societal issues (over 60% of respondents), entrepreneurial skills (over 60% of respondents), and interpersonal and management skills (over 50% of respondents) [2].

## REFERENCES

While these skills are likely to be important for nearly all scientists, the Center will analyze the web-based survey and conduct additional interviews to explore the effect that nanotechnology is having on these and other skill needs.

### 5.2 Changing Skills Requirements of Technicians in Manufacturing

Many of the aerospace, biotechnology, and microelectronics companies located in Arizona are engaged in the production of devices, materials and products in the Phoenix and Tucson metropolitan areas.

Arizona currently has a large and growing number of technician-level workers within its labor force. There are currently approximately 15,000 technicians employed in the Phoenix metropolitan region, with this number expected to grow by 25% over the next two years [10]. These technicians are employed across the three industries of focus included in this report and some of these technicians are currently working with nanotechnology, or will be working with nanotechnology in the near future.

The skills necessary for technicians producing materials, devices and products with nanotechnology may be similar to those of technicians that are not involved in nanotechnology. However, the use of nanotechnology may require new specific skills that are lacking by the region's current technicians.

The Heldrich Center will analyze the web-based survey and conduct additional interviews to determine the effect that nanotechnology is having on the workforce and skill needs of companies engaged in manufacturing.

## 6 NEXT STEPS

Throughout March and April 2007, the Heldrich Center will be completing the analysis of the effect of nanotechnology on the skill and workforce needs of high technology companies in Arizona. This additional analysis will be fully incorporated into the paper to be presented at the Nanotech 2007 conference. A written copy of this revised paper will be available to interested individuals at the conference. In addition, individuals interested in additional information can contact the authors directly.

In 2008 and 2009, the Heldrich Center will conduct similar research on the skill and workforce needs of companies using nanotechnology in two additional metropolitan regions of the United States.

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