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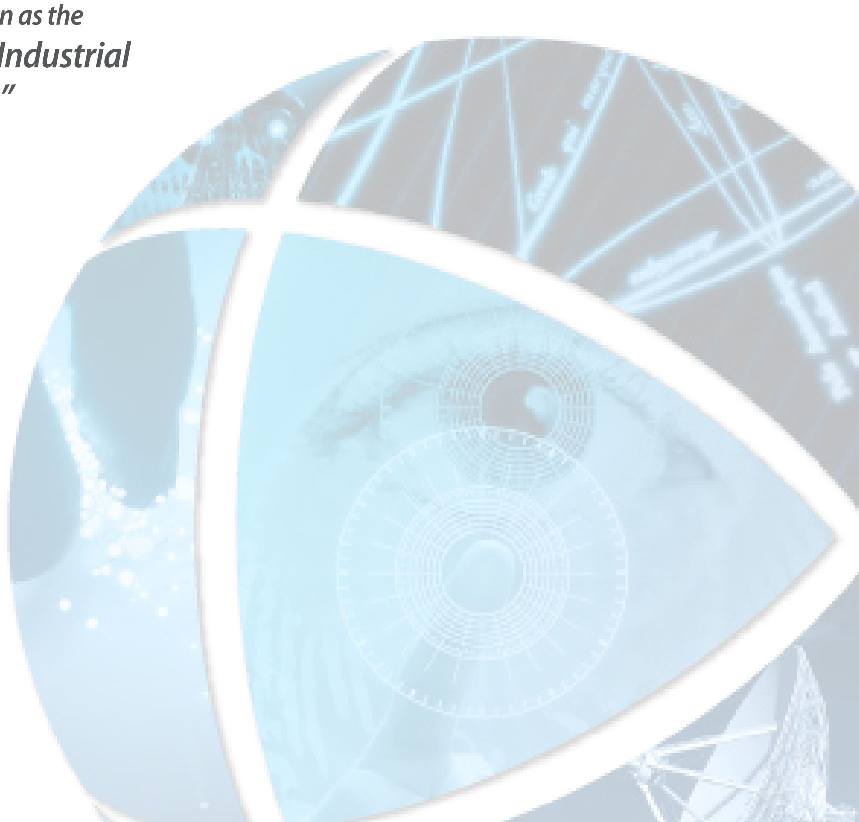

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Introducing a Nanotechnology Curriculum and Considerations for Bridging Academic/Industry Relationships: An Overview and the New Challenge for ATMAE

By Dr. Dominick E. Fazarro, Dr. Deb Newberry, Dr. Walt Trybula, and Mr. Jim Hyder

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ABSTRACT

This paper discusses an envisioned nanotechnology curriculum in the field of industrial technology. To create a dynamic industrial technology 21st century workforce, a strong collaboration between academia and industry is required. Furthermore, building this new workforce requires proactive and out-of-the-box thinking to implement nanotechnology-based programs in anticipation of industry needs. As nanotechnology becomes more persuasive, industry's demands for high technology, i.e. nanotechnology, management skills will originate from applied-technology programs. The Association of Technology, Management, and Applied Engineering (ATMAE) must be in position to assist in supplying the nano-white collar workforce.

INTRODUCTION

By 2015, there will approximately be two million workers globally in nanotechnology (Roco, 2003). Introducing nanotechnology or any emerging technology into an educational environment can present a challenge both in creating an understanding of the topic and conveying the subject's career potential. According to Lin and Allhoff (2007), "… most people are first introduced to nanotechnology through fictional works that posit scenarios" (p.3). Typically, new technologies start as a few comments in the technical publications and evolve into the widespread media as wild projections on how these developments can either create a wonderful future for everyone or destroy the planet. The truth is usually somewhere in between. During the early awareness stage, students are most eager to absorb any and all information. With the rapid pace of technology evolution, it is critical that educational institutions serve as the trusted resource for both students and industry and serve as the pioneer for training the future workforce.

The above mention of "science fiction", with some truth and some rumors, and the need for skilled and educated employees are both especially true for nanotechnology. Science and application of knowledge at the nanoscale will affect every market segment within the next decade. Academia and the professional organizations that serve them, such as the ATMAE, must be prepared to address this challenge of nanotechnology education in proactive and anticipatory ways. The National Science Foundation (2003) defines Nanotechnology as "the ability to manipulate individual atoms and molecules, making it possible to build machines on the scale of human cells or create materials and structures from the bottom up with novel properties. Students who will engage in this new technology not only need to comprehend new technical principles but must also recognize the implications and impact of nanotechnology.

Educational Challenge and Influence

For any emerging technology being taught, the initial educational focus is to ensure that students are cognizant and conversational with the fundamentals of the technology. Then, as a technology matures and moves into mainstream manufacturing applications, students will need to understand the properties of manufactured materials. In addition to content preparation and the beginning of mainstream education, tools and equipment must be made available that can be used to facilitate the understanding and manipulation of any new materials or properties (Saxton, 2007).

By developing educational programs at the early stages in the evolution of the technology, students will be better prepared to move into advanced careers as the technology advances. A solid foundation of the "basics" of a new technology allows students to adapt and contribute with minimum additional training by the employer. This emphasis on learning the fundamentals provides students with an advantage of being more employable within the emerging technology area in multiple market segments. For nanotechnology, understanding the basics at the nanoscale can enable career opportunities in electronics, biotechnology, materials and coatings as well as the food industry depending on the focus of the educational program.

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Mr. Jim Hyder is an Industry Liaison and Innovation Coach for Southwest Center for Microsystems Education (NSF-ATE Regional Center) at the University of New Mexico. Mr. Hyder was a Module Team Training Leader (Training Program Manager/Instructional Designer), Advanced Lean Practitioner, Kaizen facilitator, and Lean Simulation Coordinator within the semiconductor manufacturing industry. In this capacity he was responsible for all of the training readiness of approximately 100 Manufacturing Technicians and 20 Engineers across multiple functional areas within a fabrication environment, and provided lean education across the factory. Mr. Hyder contributed to and published 64 training documents pertaining to 300mm semiconductor manufacturing with an emphasis in the Planar and Thin Films functional areas while in a Research and Development fabrication environment. He was also a Planar and Thin Films technician for nearly two years. Early in his career Jim served as an Electronics Technician for seven years in the United States Navy, serving aboard two nuclear submarines. Contact Jim Hyder at jkhyder@msn.com.

Industry Influence

During the initial stages of any emerging technology curriculum, academia must interface with their customer – Industry. Historically, small businesses can be attributed as the primary source for new job creation (SBA.gov, 2011) but for emerging technologies, large, well-established companies will also look for skilled new employees or require an upgrade in the training of current employees. There is no doubt that having strong connections between educational institutions where education occurs and the needs of local industry – both small and large companies - will contribute to the economic growth of the region. The question is then, how does a community define the needs for an educated workforce? Lightfeather & Aznar (2011) highlighted comments by Dr. James Murday on the issue of workforce development. He stressed,

> *Despite the lack of quantitative data, industry workforce needs are varied, growing, and expected to change through time. At the outset, an emerging technology such as nanotechnology likely will affect industry at the research level and companies will seek scientists and engineers with advanced degrees to introduce and incorporate new concepts into products and services (p. 174).*

Historically, the existing business environment provides guidance to the emerging technology research community often through collaborative efforts between academia and industry in research labs. This has also been the case for nanotechnology. This collaboration supports the needs of industry for Masters and PhD level researchers within the corporation but does not often support the development of skills needs at technician or Bachelors level careers. A thorough understanding of the workforce needs of these companies can drive the educational effort, but it requires that academia strengthen ties with companies to guide the emerging technology educational climate.

This paper will explore how to meet the needs in four-year nanotechnology curriculum that address the needs of industry.

THE ACADEMIC/INDUSTRY COLLABORATION

Without any question, the development of any focused effort on education requires the collaboration with and among many organizations: state and local government officials, academic faculty and administrators, and representatives from industry and the corporate world. This collaboration needs to move beyond a casual relationship to an intentional development of a true partnership that is mutually beneficial. Collaborations between academia and industry can be leveraged through a discipline-defined professional association. For example, American Society of Engineering Education (ASEE) and the National Society of Black Engineers (NSBE) have Fortune 500 partnerships throughout the United States. The Association of Technology, Management, and Applied Engineering (ATMAE) has an external council exclusively for the organization, the National Industrial Advisory Council (NIAC). These professional organizations often assist in building bridges with educational institutions at multiple levels and through formal and informal channels.

Industry

One of the most beneficial partnerships required for the successful implementation of nanoscale content into any educational curriculum, is the bond between industry and the educational institution. Industry can provide engaging demonstrations and examples of how nanoscale concepts are being applied to create new processes and products – often in a non-proprietary format. This type of interaction and information not only engages students who are "scientific" or research oriented, but more importantly can provide the incentive and interest to keep students in STEM programs.

There are benefits in both directions for academia/industry partnerships. First, these partnerships are helping to create the technically – nano- savvy employees that industry will need. Industries associated with educational programs often get "first pick" of the graduates. Second, industry involvement helps guide the curriculum and content created for the courses. This insures that graduates are knowledgeable on subjects that industry requires. In many cases, this relationship can involve students at all educational levels. For example, in Dakota County Technical College, freshmen work on research problems/service projects or questions that are posed by industry (Newberry, 2011). This work is non-proprietary but often involves multiple aspects of an engineering or technical problem. For example, in the fall 2010 semester, a company that currently runs a manufacturing line that makes plastic products posed the following question, "What are the technology and manufacturing issues associated with converting the current product line to a biodegradable plastic?" In researching to answer this question, students had to investigate biodegradable materials involving organic nanoscale particulates, regulatory issues, current manufacturing approaches, materials, and production cost tradeoffs. The project was much more than a technical exercise but also pulled together multiple aspects of critical thinking, teamwork, traditional science and nanoscience. This combination of technology understanding and investigative, inquiry based thinking is the combination of skills that the DCTC industry partners are looking for.

However, the benefits of academic/industry partnerships must be presented with complete cooperation and understating of respecting each other's "turf". The level of cooperation between academia and industry can vary by time invested and resources on both sides. Universities that possess large number of science and engineering students can strengthen industry ties through continuous research projects (Turi-Bicaki & Brint, 2005). This is an attractive selling point for industries that seek specific expertise. Industry can devote engineers or scientists to work with the students, bringing "real world" applications and constraints into the research environment.

Academia

Universities with engineering and technology programs must take a bold step to develop nanotechnology programs (Fazarro, 2011). As nano research progresses into the 21st century, academic administrators must proactively prepare to implement programs to assist in the growth of a nano-savvy workforce. The role of four-year institutions is to develop nano white-collar workers, research, and future graduate students. Leveraging state, federal, and industry funds will be vital in starting these programs.

Bridging Industry and Academia – Different approaches

Face-to-face meetings, focus groups and panels are all important venues available to start meaningful relationships. For example, in 2010, a panel discussion involving University of Pennsylvania, Drexel University, and Army Research Laboratory (ARL) focused on the development of commercialization process incubators for nanotechnology (Luminogenics, 2010).

Industry focus groups often prove to be an efficient means of collecting information from industry regarding the skills, knowledge and abilities that they require in their employees. The focus groups can be organized around a particular market segment or at a particular grade level of employee. The members of the focus groups are often found via quick and easy surveys. In the surveys, respondees are asked, for example, if they are doing nanotechnology work within their company, if they plan to hire nanoscience knowledgeable employees and if they would be willing to participate in a two-hour focus group. The discussion from the focus group is documented and used as the basis for the educational content within a curriculum. Focus groups are usually held in the initial stages of program development and are a onetime occurrence.

Another variation on a focus group often occurs at conferences sponsored by professional organizations like the ATMAE. In this format, side meetings are requested and set up between educators and industry for the specific purpose of determining the needs of industry. These meetings are often topic (say, nanotechnology) specific rather than local or regional.

Industry advisory boards are used extensively by educational institutions to create, modify, assess and improve educational content. These boards have a critical role in ensuring that the "lessons taught" meet the needs of the industry "customer". Industry advisory boards often support the program over an extended duration.

In the case of focus groups, face-to-face meetings or even industry advisory boards, it is important that the educational committee have a certain degree of knowledge about the industrial segment. In many cases, academic educators have no knowledge of the industrial or corporate worlds. This lack of familiarity can result in miscommunication, misunderstanding and frustration. Therefore, it is sometimes necessary to have a "translator" or an industry liaison. The industry liaison often works or has worked in industry and can serve the educational community by facilitating industry skills, knowledge and abilities (SKAs) into teachable content.

The Southwest Center for Microsystems Education (SCME) provides one such example of developing bridges between industry and education. SCME is a National Science Foundation Regional Center of Excellence funded by the National Science Foundation, Department of Undergraduate Education #0902411 and focuses primarily on two-year Micro Electromechanical Systems (MEMS) technical education. Program graduates may either move on to four-year institutions or directly enter the workforce.

According to Dr. Matthias Pleil (2009), SCME's Principal Investigator,

> *The SCME offers professional development and educational materials to excite and engage secondary and post-secondary students in the field of Microsystems (MEMS) technology. This is a fast growing, multidisciplinary field. Microsystems products are found in all the gadgets we use today and require a high level of technical skills by the people who manufacture, design and integrate these devices. By engaging students in learning where these Microsystems are used, how they are made and why they should care, we, as educators, can get them to see the relevancy and importance in learning Science, Technology, Engineering and Mathematics (STEM) (para. 1).*

SCME is new to the ATMAE as of 2011, and asserts that "In the world of advanced technological education, nano-technology enables micro-technology, and micro-technology enables nanotechnology, and an educated workforce enables micro and nano commercialization" (Hyder, 2011). SCME employs an "Industry Liaison". The following describes the role of the Industry Liaison:

The Principle Investigator and Industry Liaison partner to determine how best to begin and continually improve ways to utilize and communicate with an Industry Advisory Board. The Industry Liaison's primary role is to provide a direct conduit from SCME to industry and from industry to SCME. The industry liaison supports this role by seeking synergistic opportunities, providing networking venues for industry and academia, seeking new members and organizing the Industry Advisory Board meetings, documenting results and findings, solicit financial and in-kind support from industry and define partnerships for funding opportunities.

In summary, there are many approaches and methods for establishing the critical relationship between academia and industry. These partnerships must be initiated at the onset of the program development and continue for many years, with industry serving as advisors, assessors, reviewers and the hiring entity for program graduates.

CONCEPT CURRICULUM

After a certain level of understanding of the needs and expectations of industry are defined, the educators can move into the process of creating the educational content. The educators must acknowledge that this creation process should be iterative, with feedback requested from industry upon review of the educational content, modifications and improvements made etc. This is a circular path for a time and the educational institution must plan for this review cycle and the time it takes.

Conceptual Framework

The conceptual content framework must consist of four components: theoretical, applied, societal, and ethical. To implement a nanotechnology curriculum, a *multidiscplinary approach* is required to assist in the identification of target areas within each component. This allows faculty with relevant expertise to be used to develop courses (Sheeparamatti and Kadadevaramath, 2007). With the Sheeparamatti and Kadadevaramath (2007) approach, there is a need to collaborate with industry because of advances in products to incorporate new knowledge in the curriculum.

To create this unique curriculum, *Developing a Curriculum* (DACUM) process will be facilitated with curriculum developers and industry personnel. The DACUM is a focused approach to understanding what the needs of industry are and the level of depth required in the educational portion. This approach is most feasible when there may be different and conflicting opinions about content for the curriculum. In addition, while creating the curriculum, partnership can be developed through discussions and creation of ideas during the sessions. Four components will provide a holistic learning experience in preparing nano graduates as illustrated in figure 2. Students will receive an interdisciplinary as well as multidisciplinary knowledge.

FIGURE1: CONCEPTUAL FRAMEWORK FOR FOUR-YEAR NANO CURRICULUM

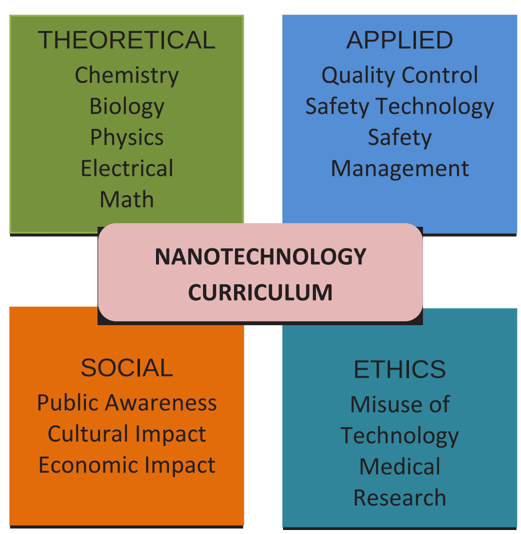

Figure 1. Conceptual Framework for four-year nano curriculum. From 2008 "Future Shock: What would a Nanotechnology Curriculum Look Like" ACTE Conference, Charlotte, NC, December 4-6, 2008 by Dominick E. Fazarro

The curriculum must also be meaningfully combined with theory and hands-on exposure to techniques and various tools that image at the nano-scale (Fonash, 2009). See figure 2. In any curriculum, as students progress, they gain conceptual depth and instrumentation experience. Upper level students are often involved in product characterization or measurements involving nanoparticles or materials. These students are pulling together the various aspects of the requirements designated in Figure 1. These aspects include design of experiments, statistical measurement, quality control, data analysis, teamwork and interaction and report writing. The knowledge gained from these activities benefit students and industry in a synergistic fashion and although not technical topic specific are required by industry as general foundational knowledge. Therefore, the educational institution cannot focus solely on the specific technical area and potentially w these topics.

Introductory and Advanced Courses

A proposed curriculum is presented for training of a white collar nano-savvy employee. This person will need an understanding of the basics of business as well as the basics of nanotechnology and how to combine the two. A level of understanding of various advanced technical concepts is also required. The curriculum and courses discussed in this section are not intended to be created from the ground up but aspects of content could be used from the myriad of nanotechnology courses and programs that have been started it the last decade.

In many courses within traditional science and engineering disciplines, material properties, forces and interactions that are predominate at the nanoscale are often mentioned. The issue is that these nanoscale topics are often given a casual or cursory review without any correlation to state of the art research or potential applications. For example, a critical aspect for propagation and control of light within a semiconductor/combination material is the relationship between the energy (wavelength) of the propagated light and the crystal lattice structure of the material and associated interfaces. This relationship is also important in understanding x-ray diffraction, standing waves on a string, and diffraction gratings. An acceptable result is only obtained when there is an appropriate relationship

FIGURE 2: MULTIPLE SKILLS, KNOWLEDGE AND ABILITIES MODEL FOR POTENTIAL NANOWORKERS

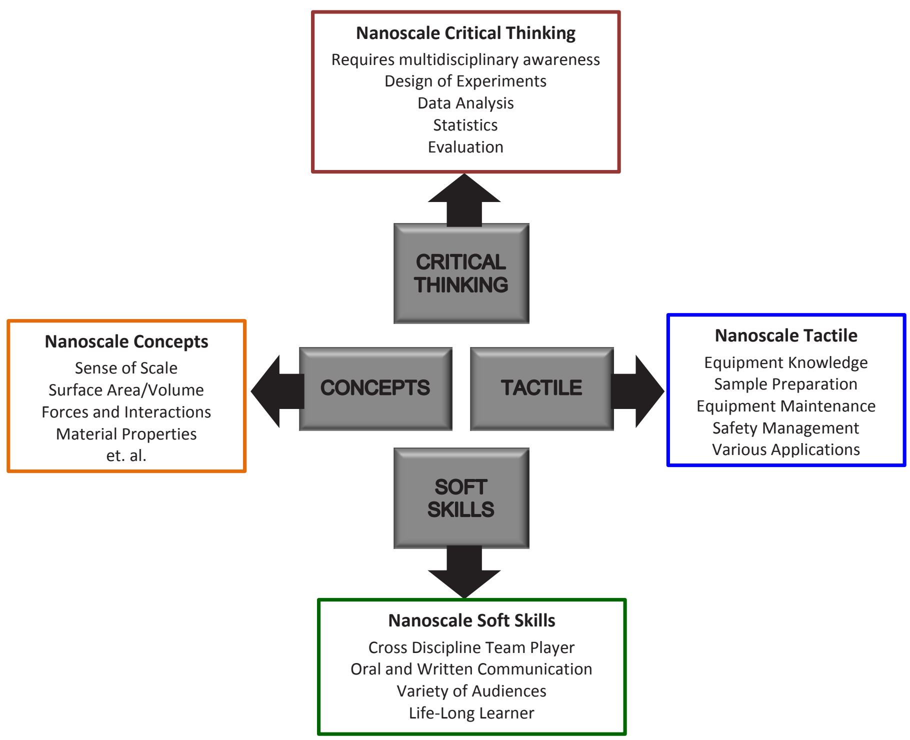

Figure 2. Model of pertinent skill sets for developing nanoworkers. Adapted from "Overviews of Nanotechnology Workforce Programs- Dakota County Technical College (DCTC)," by Deb Newberry, 2011 in J. Light Feather & M.F. Aznar (Eds.), Nanoscience education, workforce training, and K-12 resources p.182. Copyright 2011 by Boca Raton, FL: CRC Press.

between the energy and the geometry. During the discussion of any of these items, if an emphasis is placed on this relationship and references made to the ground breaking research that is occurring in the area of photonics – then nanoscale science is being taught. Discussions of these topics, at least at some level, are often a part of introductory science and applied engineering courses. By using this approach, "nanoscale" thought and considerations are not dealt with as a separate entity but as an integral part of an existing course work. Information must be taught in an applied engineering/technology format to integrate engineering principles with "hands-on" experiences without drowning students with theoretical content. Implementation of nanoscience in this manner rests primarily on the lead professor for the specific course, which should maintain a balance of theory and practice. The curriculum must illustrate the balance to provide a meaningful learning experience. Table 1 illustrates a concept of an applied nanotechnology program.

As always, multiple approaches are available. Another approach to introduce or emphasize nanoscale components is to create a survey "nano-specific" course that covers topics that are traditionally discussed at the macro or micro scale and emphasizes how these subjects are addressed at the nanoscale. Issues with credit limits and "optional" versus "required" aspects of such a survey course can also pose problems. Creation of a separate course requires interaction between the professors teaching the traditional courses and the "survey" class instructor. It is envisioned that a large selection of courses, which are conceptualized below, would provide the ability of institutions, with different requirements from the local employers, to select from such a list to create the curriculum that would satisfy the needs of both students and the community. This would provide a baseline of courses that would have a commonality of content throughout the country and ensure that basic concepts are covered.

Advanced courses are driven by industry requirements and consist of in-depth content pertaining to the manipulation and fabrication of nanomaterials. These courses will incorporate contextual learning to assist students in building their problem-solving skills. In cases whereas equipment may be too

TABLE1: CONCEPTUAL FOUR-YEAR PROGRAM: NANOMATERIAL APPLIED TECHNOLOGY-EMPHASIS IN FABRICATION

Course Prefix	Level	Credit	Designation	Course Name
NANOTECH	100	1	L	An Understanding of Fundamentals of Nanotechnology
NANOTECH	110	3	L	Ethical & Societal Issues of Nanotechnology
NANOTECH	200	4	LB	Principles of Nanomaterial Safety
NANOTECH	210	3	L	Legal Issues and Commercialization
NANOTECH	300	3	L	Principles of Commercialization of Nanomaterials
NANOTECH	310	3	L	Management and Documentation of Nanomaterials
NANOTECH	320	4	LB	Principles of Nano Physics (applied)
NANOTECH	330	3	L	Principles of Nano Electromechanical
NANOTECH	340	3	L	Introduction to Biotechnology
NANOTECH	400	3	L	Introduction to Nanomaterial Fabrication Equipment
NANOTECH	410	4	LB	Principles of Nanofabrication Technology
NANOTECH	415	4	LB	Principles of Thin Film Utilization
NANOTECH	420	3	L	Principles of Nanoscaled Material Processing
NANOTECH	430	3	L	Managing and Marketing of Nanomaterials in Products
NANOTECH	440	6-8	RFE	Capstone Research/Internship Course

Note: Key of designation: L=Lecture, LB=Lab, RFE=Research Field Experience expensive to purchase, there is an option of creating virtual environments with a realistic appearance allowing students to feel that they are actually in the lab (Fazarro, McWhorter & Lawrence in-press). Specific nanotechnology courses could serve as a basis for delivering focused and high-tech courses that meet workforce requirements.

THE ROLE OF ATMAE

The Association of Technology, Management, and Applied Engineering (ATMAE) has been an active association for over 45 years. The organization has changed and moved forward to maintain pace with rapid changes in technology. ATMAE is considered to be Industrial Technology instructors' main venue to present and publish papers. By adding areas of nanotechnology to ATMAE, the organization is diversifying other new technology areas to accommodate scholars and other post-secondary instructors.

Currently, with the support of ATMAE and individuals in areas of nanotechnology, there is a focus group and a presentation track for the ATMAE conference in 2011. As nanotechnology gains momentum, in the future, the organization will be positioned to accredit programs/emphasis in nanotechnology.

CONCLUSION

The purpose of the concept program is to give students a broad but specific area to target potential contributions to the field. To obtain well prepared students, cooperation between secondary schools, two year schools, and industry must be paramount. Education and Industry sectors must be more proactive to build the 21st century workforce to compete globally. Even though this paper provides a future look of a four-year nanotechnology program, there will be a need for academic and industry collaborations to determine how to teach certain skill sets, such as the ability to use tools and technology to build nano products. This journal article provided one such model to build such collaborations. Developing nanotechnology programs will be the backbone for providing a new 21st century white collar workforce. ATMAE's mission will be a perfect, foundation and rationale to developing nanotechnology programs. Using an analogy of expanding a house, ATMAE will have to eventually expand the house/intellectual community by adding another room for this emerging innovation — nanotechnology. ATMAE will also play a key role as a mouth piece to generate focus and purpose of implementing a new technology-applied curriculum throughout the ATMAE community.

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