Promoting Excellence in Preparation and Excellence in Practice

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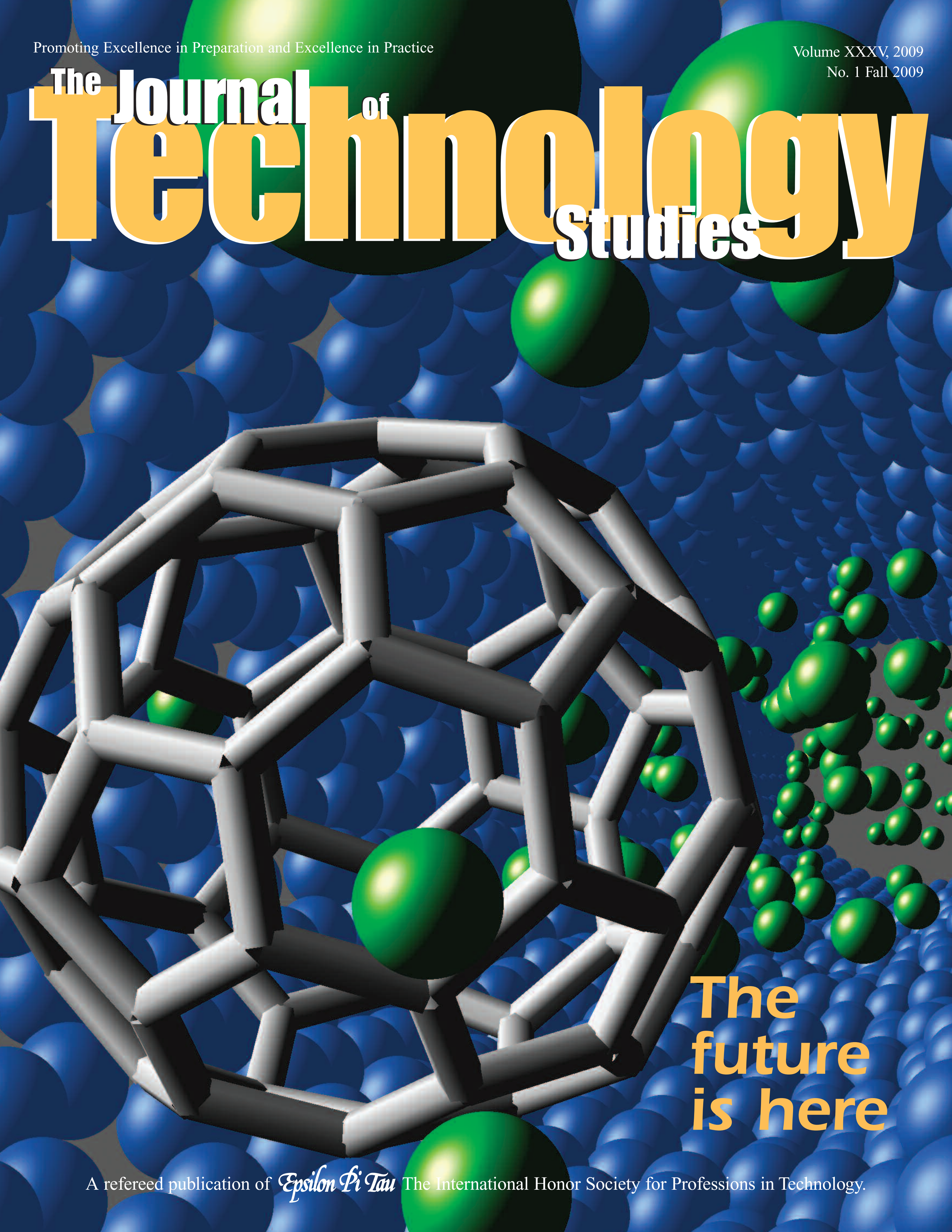

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A general guide to the breadth of topics of potential interest to our readers can be gained by consideration of the 17 subclasses within "Technology" of the classification scheme of the Library of Congress, USA <lcweb.loc.gov/catdir/cpso/lcco/lcco_t.pdf>. This includes engineering and allied disciplines, informatics in its many manifestations, industrial technology, and education in and about technology.

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Table of Contents

Volume XXXV, Number 1, Fall 2009

Journal of Technology Studies

Forewords by:
Dr. Walt Trybula-Director Nanomaterials Application Center (NAC), Texas State University and Deb Newberry-Director-Nano-Link Regional Center, Rosemount, MN

This issue of the *Journal of Technology Studies* is addressing a topic that has been characterized as the most important technology since semiconductors and the future of manufacturing opportunities over the next few decades. While this possibly is an overstatement, nanotechnology is creating numerous, exciting possibilities. It is very early in the development of the technology. In some areas, the development of nanotechnology is just approaching where semiconductors were when Intel introduced the 4044 microprocessor! A growing future lies close by with limits beyond imagination. This is a critical time in the evolution of this technology.

This issue of the J*ournal of Technology Studies* is a beginning step in creating an understanding of the needs for the appropriate applications of nanotechnology.

Walt Trybula, Ph.D., -Director Nanomaterial Applications Center (NAC), Texas State University, USA

The multi-disciplinary aspect of nanotechnology is providing an opportunity to break down the traditional walls between disciplines that exist at research institutions. Conveying concepts, providing hands-on experiences and denoting practical applications are challenges that every educator faces. These challenges are particularly significant when the technology or subject is new – which is the case for nanoscience. Researchers, educators, industry, and government are all on unfamiliar ground when dealing with nanoscience. By working together, sharing information and discoveries the map of that terrain will be efficiently map – however it will be a long and arduous process. This special topic journal issue is a step in the right direction.

Deb Newberry
Director-Nano-Link Regional Center
Rosemount, MN

Nanotechnology Education: Contemporary Content and Approaches

Jeremy V. Ernst

Abstract

Nanotechnology is a multidisciplinary field of research and development identified as a major priority in the United States. Progress in science and engineering at the nanoscale is critical for national security, prosperity of the economy, and enhancement of the quality of life. It is anticipated that nanotechnology will be a major transitional force that possesses the potential to change society. Rapid and continued advancement in the field of nanotechnology is accelerating the demand for specific professional knowledge and skill. These lines of technological discovery and improvement continue to unlock new content for classroom incorporation.

Contemporary approaches and practices to further engage learners and enhance their abilities to apply nanoscale-related content knowledge must be continually developed in order for the United States to solidify itself as the primary builder of nanotechnology research and development. Steadfast development of new technologies leading to continual transformation of society serves as a strong indicator that current educational practices should be altered in order to prepare knowledgeable and engaged citizens. The use of three-dimensional graphics, virtual reality, virtual modeling, visualizations, and other information and communication technologies can assist in reinforcing nano-associated scientific and technological concepts.

Introduction

High-level content of pressing importance addressed through contemporary approaches is an identified necessity in educational systems. Development and innovation are critical components of education in the United States; they promote the maturity of an educated, skilled, and creative general public. Emerging technologies, such as medical technologies, biotechnologies, and especially nanotechnologies represent prosperous areas for the workforce and the economy, and therefore, they can be a driving force in career and technical education. According to trend analysis, the future will be largely dominated by amplified use of nanotechnologies (The National Academies, 2006). Longitudinal analysis leaves little uncertainty that nanotechnology will guide a key transformation with a significant impact on society (Mnyusiwalla, Daar, & Singer, 2003).

Although there has been a steady growth in global nanotechnology, this dominating trend is especially true for the United States. The National Academies (2006) indicates that 33 percent of all nanotechnology patents awarded from 1990 to 2004 were granted to researchers in the United States. Japan was second, with 19 percent of the worldwide patents during the same period of time.

Shelley (2006) indicates that determined research and development for targeted nanoscience and nanotechnology has resulted in discovery and application now culminating in marketable products and new commercial applications. As more products (e.g., sunscreens, cosmetics, clothing, upholstery, paint, bodywork of vehicles, computer components) utilize nanotechnologies, it is only a matter of time until nanotechnology infiltrates consumer products holistically. Shelley (2006) further identifies the limitless possibilities that applying nanotechnology presents. He asserts that the span and reach of nanotechnology should become and remain a primary consideration not only in government and commerce but also in education. This consideration stems from nanotechnology's application to energy, medical, and information technology, which are both essential and developing components of today's society. The purpose of this article is to introduce nanotechnology/nanotechnology education, its societal and economic significance and its importance as an area of study. Also provided are examples and recommendations on the implementation of nanotechnology into teacher-preparation programs.

Literature Review

The National Aeronautics and Space Administration (as cited in Mnyusiwalla, Daar, & Singer, 2003) identifies the field of nanotechnology as focusing on the formation of purposeful materials, devices, and systems through the management of matter on the nanometer scale, and the utilization of new occurrences and attributes at the scale. Lakhtakia (2006) indicates that nanotechnology is not a solitary method; neither does it engage a precise variety of resources. Instead, nanotechnology encompasses all facets of the fabrication of devices and systems by influencing material at the nanoscale. In education and the sciences, advances in nanotechnology and technology as a whole are blurring the lines between disciplines (Schank, Krajcik, & Yunker, 2007).

Nanotechnology is truly a multidisciplinary field that includes individuals from chemistry, physics, biology, materials science, and engineering all working in a collaborative manner to better understand and apply knowledge of objects that meet the scale classification (Clark & Ernst, 2005). Advancements in bioengineering, instrumentation, materials science, and manufacturing diminish the distinguishing characteristics of science and technological disciplines (Jacobs, 1996). Rapid discovery, development, and advancement have resulted in relationships among science, technology, and society becoming increasingly stronger. Unfortunately, schools find it difficult to modernize curricula given the pace of innovation (Fourez, 1997).

Progress in science and engineering at the nanoscale are critical for national security, prosperity of the economy, and enhancement of life quality for society as a whole. The National Science Foundation has identified that a major outcome goal of the United States is the development of "a diverse, competitive, and globally engaged U.S. workforce of scientists, engineers, technologists and well-prepared citizens (2004, p. II-7)." It has been projected that approximately two million workers will be required worldwide during the next decade. Many science, engineering, and technology disciplines converge at the nanoscale, because they consist of many common principles and tools of investigation (Rocco, 2002). By 2015, it is predicted that nano-related goods and services will be a market in excess of one trillion dollars (Ratner & Ratner, 2003). Thus, nano businesses will become the fastest growing industry in history, outranking the telecommunications and information technology industries combined.

Nanotechnology will have an impact on war, crime, terrorism, law enforcement, and commercial goods (Wilson, Kannangara, Smith, Simmons, & Raguse, 2002). The military has a broad interest in nanotechnology, which spans optical systems, nanorobotics, nanomachines, smart weapons, nanoelectronics, virtual reality, armors, energy-absorbing materials, and bio-nano devices. Quite possibly the most important areas of research and development concerning nanotechnologies are nano-optics and nano photonics. Advancement in these areas has potential to create new industrial and manufacturing processes and uncover new ways to maintain a clean and sustainable environment. Although much of the benefit of nanotechnology is anticipated, applications of nanotechnology are not all categorized as futuristic. Manufacturers are currently producing products with nanoproperties. Many materials in current use are products of nano-related research, such as stain repellents, water repellents, and dental fillers. Much of the invention and innovation in nanotechnology is dependent on associated processes. In order to manufacture at a smaller and smaller level, instruments and chemicals must be used with extreme precision. Industrial and manufacturing process applications of nanotechnologies represent the foundation of further discovery. These applications that merge biology, chemistry, medicine, and fabrication are broad-based areas that exhibit great potential for cross-disciplinary approaches to education.

Heightened need for targeted knowledge and skill will most certainly have an imprint on the educational system at all levels. The identified "blurring" of disciplines plays much into the emerging structure of an integrated systems approach in technology education classrooms across the country. Shields and Rodgers (2005) identified the need for heightened awareness of experimental technologies for technology education students. The competencies identified in their study are students' abilities to recognize the ramifications of green energy, efficient vehicles, biometrics, and nanotechnology, many of which demonstrate a direct relationship.

> A key challenge for nanotechnology development is the education and training of a new generation of skilled workers in the multidisciplinary perspectives necessary for rapid progress of the new technology. The concepts at the nanoscale (atomic, molecular and supermolecular levels) should penetrate the education system in the next decade in a manner similar to the way the microscopic approach made inroads in the last 50 years. Furthermore, interdisciplinary connections reflecting unity in nature need to be promoted. Such education and training

> must be introduced at all levels, from kindergarten to continuing education, from scientists to nontechnical audiences that may decide the use of technology and its funding. (Roco, 2002, pp. 1247-1248)

Technological discovery and improvement continues to unlock new content to incorporate into the classroom. Elevated subject matter and classroom experiences that feature cutting-edge approaches are essential to develop knowledge and motivate students at the K-12 level (Sweeney, 2006). Sweeney further identifies that future progression in nanoscale science and engineering will rely on the content and quality of education in the K-12 classroom. Schank, Wise, Stanford, and Rosenquist (2009) concluded from a recent study that suitable preparation and guidance for teachers, paired with well-designed and engaging nanoscience curricular activities are necessary to facilitate student concepts of the fundamental principles that preside over the performance of particles on the nanoscopic scale.

Curricular activities that incorporate real-world examples can enhance students' attitudes about science and emerging ideas. Jones, Andre, Superfine, and Taylor found in a 2003 study that students can increase their understanding of what the nanoscale is through development of high-quality three-dimensional graphics and utilization of virtual reality software. In a 2006 National Science Foundation project, Chizmeshya, Drucker, Sharma, and Carpenter identified that direct and virtual microscopy practice by students establishes scale knowledge at the nano level and provides a constructive source for computer modeling experiments. This grouping provides an opening for students to take part directly in nanoscale materials research at an appropriate age and with suitable content.

Scale remains one of the most difficult concepts for students to grasp regarding nanotechnology. Relating nanometers to customary units of measure provides a minimal level of awareness of actual nanoscale objects. However, the relation of visible and tangible objects that students perceive as extremely small can accentuate this knowledge for students. Table 1 is an example that standardized units as well as tangible, visible, or represented objects as comparisons to the nanoscale.

Table 1. Comparisons to the Nanoscale

One meter = One billion (1,000,000,000) nanometers
One inch = 25,400,000 nanometers
A human hair = approximately 50,000 nanometers in diameter
Bacteria (single-celled microorganisms) = from a few hundred to 1,000 nanometers across
10 hydrogen atoms in a line = 1 nanometer

Note: Table information courtesy of the VisTE Project

Approaching scale through exponential means with a graphical representational basis is also an effective mode for approaching this type of material (Wiebe, Clark, Ferzli, & McBroom, 2003). Clark and Ernst (2005) report findings of a three-year study linking science and technology concepts through the creation of visualizations. The study involved the creating, piloting, and field testing 12 instructional units for technology education in grades 6 through 12 (typically ages 11-18). The intent of forming instructional units in the US educational system is to organize information on a topic into lessons, taking into consideration time, materials, and preparations. The instructional units cover topics on agricultural and related biotechnologies, medical technologies, nanotechnologies, and principles of visualization related to fields studied in pre-engineering curricula. Study data indicates that students who participated in the instructional units involving the creation of visualizations significantly increased their knowledge in the identified content areas.

Implications for Teacher Preparation

Universities are beginning to include nanotechnology (i.e., content and practice) in their technology education teacher-preparation curricula. One specific program that includes a course partially dedicated to nanotechnology and its application is the Technology, Engineering, and Design Education Program at North Carolina State University in Raleigh: It is titled "Emerging Issues in Technology." In this course, students explore contemporary medical, environmental, and biotechnological topics. They complete associated learning activities, experimentation/data collection exercises, and modeling projects. The medical technology sequence consists of disease prevention and medical imaging technologies, investigating pasteurization, irradiation, sterilization, water treatment, sanitation, immunization, computerized axial tomography, ultrasound technology, magnetic resonance imaging, and endoscope technology.

The environmental sequence is composed of graphical weather patterns, Earth observation systems, green power, sustainability, cradle to cradle design, and renewable energy resources. The biotechnology sequence consists of DNA technology, gene detection, enzyme replacement, cell culture, and associated nanotechnologies. A major portion of the biotechnology sequence is dedicated to the study of nanotechnology. Table 2 highlights the targeted areas of study within nanotechnology, the proportional emphasis dedicated to the specific unit, and the content of each area.

Table 2. Areas of Study Within Nanotechnology

Nano Topics	Proportion	Content
Microscale and Nanoscale	15%	"Nano" and nanometer, English expression, magnitude as a number and exponent, relative size
Carbon Forms	8%	Physical properties, oxidation state, compounds, carbon form uses
Modeling and Simulation	15%	Data structuring, process structuring with choice of 3DS applications, Flash applications, Truespace applications
Water Purification	8%	Contaminants, microfiltration, porous nanoparticles, nanotubes
Nanorobotics	6%	Biosensors, control design, controlled manipulation, bio-uses
Biomedical Applications	12%	Drug delivery, bio-machines, biosensors
Future Application	12%	Fuel cells, solar cells, nanofibre armour
Risks and Benefits	12%	Security, health, environment
Nano Ethics	12%	Public safety, regulation, standards

The nanotechnology unit represents approximately 30 percent of the Emerging Issues in Technology course. Additionally, the Technology Engineering and Design Education Program offers courses in Mechatronics, Scientific Visualization, and Technical Animation. The Mechatronics course expands on nanorobotics exploration through computerized control systems, controllers, automated machines, and robots. The Scientific Visualization offering enhances computer graphics application as a problem-solving tool. Ranges of software packages are utilized to assist in the solution of conceptual and theoretical problems. In the Technical Animation course students must construct 3-D objects, spaces, and environments. The Scientific Visualization and Technical Animation courses greatly contribute to the nanotechnology modeling and simulation requirements in the Emerging Issues in Technology course. An animation still of an atomic force microscope used to manipulate atoms is shown in Figure 1. Nanomanipulation, or the ability to move atoms individually and arrive at predetermined arrangements, is an important first step in realizing the potential of nanotechnology.

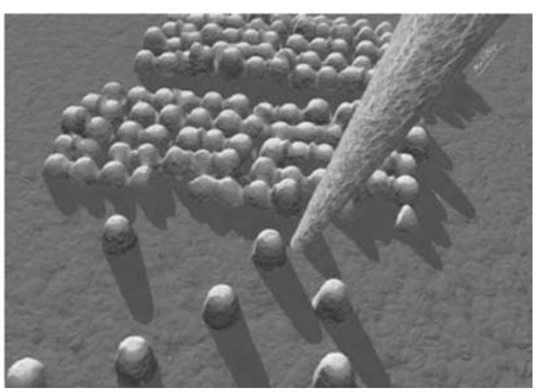

Figure 1. Nanomanipulation Animation Still (Image courtesy of the VisTE Project)

Nanomanipulation is just one aspect of nanotechnology that can be enhanced with application when interwoven throughout coursework in teacher-preparation programs.

A key to implementing the study of nanotechnology content and processes into a technology education teacher-preparation program is to provide an integrated and spiraling sequence of course offerings. These offerings should gradually build upon one another and establish layered content knowledge and performance-based application that merges identified systems-based benchmarks in a logical and connected flow. Additionally, visual examples and simulated real-world applications should be used where possible to enhance students' engagement and understanding in technology teacher education. The use of intrinsically motivating approaches, such as visual and kinesthetic learning methods, creativity strategies, problem-based learning, and learning through design are particularly effective methods for reinforcing STEM-based material (Clark & Ernst, 2007). Problem-based and project-based approaches to student learning also have been shown to improve the understanding of basic concepts and to encourage deep and creative learning despite academic content area (Powers & DeWaters, 2004). The identification of ideas derived from mathematics and science enables instructional sequences to visibly reinforce applications of concepts, skills, and principles through identified content. In this case, chemistry, physics, biology, materials science, and engineering are all disciplines central to the study, experimentation, and further development of nanotechnologies.

Conclusion

Steadfast development of new technologies leading to continual transformation of society serves as a strong indicator that current educational practices should be altered in order to prepare knowledgeable and engaged citizens. Contemporary approaches and practices to further engage learners and enhance their abilities to apply nanoscale-related content knowledge at the highest level must be developed continually, in order for the United States to solidify itself as the primary mover of nanotechnology research and development.

Modeling and visualizations reinforce associated scientific and technological concepts. The use of these associated communication technologies heightens student involvement and strengthens individual technological and scientific knowledge and abilities while providing students with an opportunity to gain a firm grasp of engineering principles behind the technologies (Newhagen, 1996). Implementing enhanced instructional tools and methods in technology and science classrooms in a coordinated structure has the potential to build content understanding of not only nanotechnology, but many of the "blurred" areas identified by Schank, Krajcik, and Yunker in their 2007 work. A true multidisciplinary approach that incorporates computer graphics and applications has been demonstrated to be effective in classroom instruction associated with nanoscience and nanotechnology (Chizmeshya, Drucker, Sharma, & Carpenter, 2006; Jones, Andre, Superfine, & Taylor, 2003; Clark & Ernst, 2006), but this approach has much more to offer technology/science and education as a whole if its proponents are provided adequate tools and support on a larger scale.

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Nano Revolution – Big Impact: How Emerging Nanotechnologies Will Change the Future of Education and Industry in America (and More Specifically in Oklahoma) An Abbreviated Account

Steven E. Holley

Abstract

Scientists are creating new and amazing materials by manipulating molecules at the ultra- small scale of 0.1 to 100 nanometers. Nanosize super particles demonstrate powerful and unprecedented electrical, chemical, and mechanical properties. This study examines how nanotechnology, as the multidisciplinary engineering of novel nanomaterials into atomically precise products, is expected to disrupt most industries.

Past industrial revolutions, driven by water power, internal combustion power, electrical power, and computer power, have greatly affected our economy and forever changed the course of society. Nanotechnology represents more potential power than all previous technologies combined. The primary methodology of this study involved comparing the current literature on developments in nanotechnology to the historical development of electricity to assess if the nanotech revolution is reaching a true "critical mass," based on acceleration of technological change today and at other times in history. Data was collected from technical and business books on nanotechnology, testimonies from scientists before Congress, policy letters from the President's Office of Science and Technology, presentations at major nanotech conferences, perspective surveys from the international to the local level, studies on the dangers and regulation of nanotechnology, and studies on the general and scientific educational landscape of America.

Although nanotechnology is growing in national academic intensity, is gathering public recognition, and is based on patentable science, Oklahoma and the West South-Central Region received only 9.6 percent of nanotech funding (NSF Award DMI-0450666, 2005). This study establishes recommendations for business and academic planning with specific strategies, goals, and objectives for community college workforce education in Oklahoma.

Introduction

The discovery and utilization of basic enabling technologies such as fire, wheels, alchemy, electricity, magnetism, metallurgy, and combustion were watershed events in the destiny of humankind. These technologies incrementally changed the thinking about reach of life and richness of life on this planet. The next watershed event is rapidly swelling as scientists discover how to manipulate matter at the molecular level to produce materials with extraordinary properties that have never before existed or been understood. These hyper-functional materials, characterized at the nano scale, have the potential to overwhelm all the collective contributions of past technologies. "Nanotechnologies will eventually disrupt, transform, and create whole industries" (Morse, 2004). Not just the industrial landscape will change dramatically but "because of nanotechnology, we will see more change in our civilization in the next thirty years than we did during all of the twentieth century" (Uldrich & Newberry, 2003). Although nanotechnology has been only a buzzword for the masses, it is approaching "critical mass" for the next "Industrial Revolution."

Study Purpose

Because nanotechnology reflects a multidisciplinary convergence of physics, chemistry, biology, and engineering, the definitions, predictions, and concerns for this emerging science/technology are biased in many directions. The purpose of this study is to bring into focus the many perspectives that nanotechnology has already created by establishing a consensus of technical facts, realistic timelines, economic potentials, security interests, and ethical issues. Nanotechnology is like a gathering storm that represents very intense yet diverse interest for all stakeholders. Like the tracking of a developing hurricane that is headed for land, this study intends to track the gathering forces of nanotechnology that are building toward the next "Industrial Revolution." The study also addresses the major impact of how the nano revolution will change the educational and industrial landscape for America, specifically in the rural sector. No industry will go untouched: transportation, agriculture, chemicals, plastics, electronics, computers, cosmetics, healthcare, medicine, and many more will benefit from this "Fantastic Voyage" to the center of matter. Nanoscale technology is not just another step toward miniaturization; it is a qualitatively new scale that requires new ways of thinking.

Study Objectives

1. Identify socio-technical relationships between past Industrial Revolutions and the development of nanotechnology from 1959 to present.

2. Establish present and pending socio-technical impacts of nanotechnology on American educational and business institutions.

3. Investigate the knowledge, attitudes, and planning of business professionals concerning the impact of nanotechnology in Oklahoma through a Chamber of Commerce sponsored survey.

Study Significance

This study is important for addressing the nonscientists on scientific issues that may very well affect their employment, health, education, finances, and security. Because of striking diversity among scientists, those outside the research community have a significant gap in practical knowledge, which leads to unsettling confusion over nanotechnology buzzwords and futuristic predictions. This study is also important for clarifying the socio-technical impact of a rapidly growing yet still technically clouded science/technology. Putting nanotechnology to work will require investing in a new generation of highly skilled technologists. This study will be significant for defining educational objectives that applied science colleges should consider to supply nanotechnologists for emerging nano product commercialization and for micro-level companies that are migrating to nano level.

Impact Survey Questions

The Oklahoma Nanotechnology Impact Survey (ONIS) was developed to further test the thesis that nanotechnology will significantly affect Oklahoma business and education. To investigate the knowledge, attitudes, and planning of business professionals concerning their view of how nanotechnology has and will impact the state of Oklahoma, the ONIS was provided as a project to the Oklahoma State Chamber of Commerce whose findings were shared with the Oklahoma Center for Advancement of Science and Technology (OCAST). The ONIS was disseminated to a database of 4,542 Oklahoma businesses. The six survey categories are (1) interest & knowledge, (2) economic effects, (3) strategic planning, (4) Oklahoma perception, (5) regulation, and (6) state support. Survey results for 2006 and 2007 are located at http://www.oknano.com/pdf/ONIS.pdf and http://www.oknano.com/pdf/NanoSurvey07.pdf.

Study Rationale

"The ability to build anything we can design, by manipulating molecules under direct computer control, will be a jolt to the system" (Treder, 2004). That jolt will be seen as technical and social developments from nanotechnology that include: novel production methods and new products with advanced properties; nano-factories that replicate more nano-factories in an exponential proliferation of manufacturing; rapid and low cost prototyping that greatly reduces product time to market; very low cost raw material and capital investment requirements that can introduce major discontinuities for the economy; and portability and secrecy of major manufacturing capability that can disrupt social norms and national security.

Consistent with the "jolt to the system" view, the rationale of this study is driven by five concerns: (1) Core values need to be evaluated based on the overwhelming properties of nanotechnology. (2) Strategic planning needs to align with the acceleration of nanotechnology development. (3) Markets and security threats need to be developed based on global competitiveness in nanotechnology. (4) Ethical applications of nanotechnology should be at the forefront of policy making decisions in business, education, and government as continued research and development reveals the ever growing potential of nanotechnology. (5) Educational and business models need to lead not follow nanotechnology developments.

Review of the Literature & Survey

What is the History and Nature of Nanotechnology?

Nanotechnology was an unexplored scientific frontier until 1959, when theoretical physicist Richard Feynman invited fellow scientists to consider the possibility of manipulating matter at the molecular and atomic levels to build ultra-small machines and information storage devices. Though Feynman was convinced that physics would allow for atoms and molecules to be individually controlled and manipulated, he did not know what tools would be required and he did not know the amazing materials that would result to form new atomic structures (Keiper, 2003). Because nanotechnology is growing rapidly and gaining momentum, it does not share a unified conceptual understanding across all disciplines and that creates a problem in defining it. "Definitions of nanotechnology are as broad as its applications" (ENA, 2004, p. 7).

Nanotechnology results from deliberate design and processes, but some confusion and controversy complicate an accurate definition by the fact that there are naturally occurring nanosize materials residual in industrial processes. Some differences in definition are of only academic interest, but "the way nanotechnology is defined in a regulatory context can make a significant difference in what is regulated, how it is regulated, and how well a regulatory program works" (Davies, 2005, p. 7).

The National Nanotechnology Initiative (NNI) encourages a strict definition of nanotechnology by including only activities at the atomic, molecular, and supramolecular levels, in the length scale of approximately 1 – 100 nm range that create materials, devices, and systems with fundamentally new properties and functions because of their small structure. The NNI definition focuses on new contributions that were not previously possible because of novel phenomena, properties, and functions at the nanoscale. The abilities to measure, control, and manipulate matter at the nanoscale in order to change those properties and functions are the hallmark of nanotechnology (Roco, 2003).

Nanotechnology is developing a very disruptive nature. In fact the view of industry experts is that "It's hard to think of an industry that isn't going to be disrupted by nanotechnology" (Uldrich & Newberry, 2003). This view of a pervasive invasion is reflected in the studies and presentations of Smalley (1999), Murdock (2002), Roco (2003), Bordogna (2003), Treder (2004), and Dareing and Thundat (2005). One way to keep the disruptive potential of nanotechnology in perspective is to ponder the disruption that would occur if electricity were suddenly unavailable. Utilities, transportation, communications, commerce, education, much of the country's infrastructure, and almost all products that we use on a daily basis would cease to operate.

Products enabled by nanotechnology will evolve, but as Treder (2004) points out – "with all that change compressed into just a few years." Bordogna (2003) is also certain that nanotechnology is not just transformational but "with nano, change is about to go ballistic." Emerging nanotech businesses that prevent health problems from occurring will displace businesses that supply cures and treatments for diseases. Similarly, if nanotechnology identifies molecules responsible for depression and assists in binding new drugs to modify those molecules then Eli Lilly who manufactures antidepressant drugs like Prozac might find that nanotechnology has disrupted their business (Uldrich & Newberry, 2003).

"Nano has been called a 'general purpose technology' to capture the expectation that – like electricity – nanotechnology will enable and reconfigure a wide range of technologies, touching most sectors of the economy" (Bordogna, 2003). The disruptive properties of nanotechnology extend beyond the science because most people do not comprehend its transformative nature and how rapid transformations could take place. Cross-discipline communications is a difficult and common behavioral science problem that nanotechnology could also address by creating technological synergy that has never before existed (Phoenix, 2003). This opportunity for synergy was recognized by Smalley (1999) when he stated that "Nanoscience is an opportunity to energize the interdisciplinary connections between biology, chemistry, engineering, materials, mathematics, and physics in education."

At the very highest levels of government, the National Nanotechnology Initiative has a very aggressive and disruptive vision that targets K-12, universities, vocational, and public domains for nanoscience and nanotechnology education. In the *National Nanotechnology Initiative Strategic Plan* prepared by the National Science and Technology Council, co-chairs Russell and Bond (2004, p. I) set four goals to accomplish the NNI vision: (1) "Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology; (2) Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit; (3) Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; (4) Support responsible development of nanotechnology."

How is Nanotechnology Perceived by the General Public?

Based on their study, Cobb and Macoubrie (2004, p. 395) conclude that "perception and knowledge are important parts of public understanding of science." Their National Science Foundation-funded survey conducted at North Carolina State University in 2004 found that 80 to 85 percent of the general public in America had not heard anything or at most very little about nanotechnology. The *"Oklahoma Nanotechnology Impact Survey"* (ONIS), which was conducted online and at business conferences during April of 2006, found that 92 percent of Oklahoma citizens were generally not informed about nanotechnology as perceived by Oklahoma business professionals. According to a "European NanoBusiness Survey" (2004), 87 percent of European citizens were either not much or not at all informed about nanotechnology (ENA, 2004). The European NanoBusiness Association (ENA) survey was biased with respondents from companies that had an interest in nanotechnology.

In 2005, the Project on Emerging Nanotechnologies published results of a study entitled "Informed Public Perceptions of Nanotechnology and Trust in Government." The report reveals that American consumers are eager to learn more about nanotechnology, and they are generally optimistic about the possibilities that nanotechnology will improve their quality of life. The public is most interested in major medical advances, particularly new and improved treatments for cancer, Alzheimer's, and diabetes (Rejeski, 2005). When Oklahoma business professionals were asked if nanotechnology will have a significant effect on the lives of Oklahoman citizens, a high percentage (78%) agreed that it would. The tension between acknowledging lack of knowledge and anticipating significant impact is striking and begs the question of how uninformed citizens may react to unfolding events that nanotechnology will engender, both real and perceived.

Public perception of nanotechnology depends on democracy and outreach to citizens. Roco (2003) recommends fostering public awareness and understanding of nanoscale science and engineering through development of media projects and exhibits that address benefits as well as unexpected consequences. Even with a negative public perception of nanotechnology, a majority of Oklahoma business professionals would continue to utilize nanotech products. A similar question in the ENA (2004) survey indicated that 74 percent of Europeans businesses would not change their attitude about using nanotechnology, even if there was negative public perception.

What Risks Are Associated with Nanoscale Molecular Manipulating?

Nanoscale agents that are produced by molecular manipulation can be introduced into consumer products to achieve certain benefits, but the penetrating properties of ultra small size also introduces certain and to-date unpredictable risks. As Germany's Federal Institute for Risk Assessment is investigating 97 cases of intoxication from a cleaning product called "Magic Nano," America's counterpart, the Food and Drug Administration, announced plans for discussions on nanotechnology materials being used in drugs, foods, cosmetics, and medical devices (Associated Press, 2006). Environmental situations are endless, ranging from the distribution of nano dust on American highways as nano-enhanced tires wear down to the eventual pollution of ground water because of the unstoppable mobility of nano size materials (Brown, 2002). Medical risk studies by Southern Methodist University and the University of Rochester have shown that carbon buckyballs (C60 hexagonal spheres) and other nanoscale materials can enter and be absorbed by the brain; however, the levels of damage and the required exposure rates are still under study (Feeder, 2004).

In most every public discourse on nanotechnology, including testimonies before the U.S. Congress and statements from the Executive Office of The President of the United States, the ethical and social concerns are elevated to a "high priority" status, yet, few decisions seem to reflect the urgency (NSF Award ESI-9730727, 2000; Roco, 2003; Davies, 2005; Marburger & Bolten, 2005). Policies become an afterthought rather than being fully integrated into the planning process. As Rejeski (2005) stated, "Our approach to social and ethical issues has largely involved an 'outsourcing' model where the scientists do the science and 'ethics' are dealt with in separate institutions and centers." Many nanotech companies already fear public reaction because of the current lack of regulation (Davies, 2005). Rejeski (2005, p. 64) recommends that we "create a Nano Safety Reporting System where concerned people working with nanotechnologies in laboratories, companies, or in shipping and transport situations can share safety issues and concerns."

In spite of the looming risks, the initial reactions to nanotechnology by Americans have thus far been mostly positive. Most Americans have a positive view of science and expect the benefits of nanotechnology to be more prevalent than the risks. When the potential benefits of nanotechnology are seen as new and better ways to overcome human diseases, people feel more hopeful about the technology. The greatest risks people express are the loss of personal privacy due to possible nano surveillance and the inability of business leaders to minimize nanotechnology threats to human health (Cobb & Macoubrie 2004). Americans do have trust in regulatory agencies as shown from a study by the 2005 Woodrow Wilson Center's "Project on Emerging Nanotechnologies." The internet can also provide opportunities to inform and involve the public (Davies, 2005).

What Economic Forces Will Drive Nanotechnology Commercialization?

Joseph Finkelstein (1992, p. XV) wrote: "We are at the beginning of a Third Industrial Revolution that will reshape not only our industrial processes but also bring with it great changes that will affect all our lives for the next century." Twelve years later, Mike Treder (2004, November), Director for the Center for Responsible Nanotechnology, wrote: "The combined impacts of nanotechnology will equal the Industrial Revolutions of the last two centuries – but with all that change compressed into just a few years." Treder's (2004) view is that we have been in the Fourth Industrial Revolution since 1950 and that we are now on the eve of the Fifth Industrial Revolution that is driven by nanotechnology.

Industrial revolutions have been observed to develop in three stages: one sector of the economy undergoes rapid change, then this sector grows more rapidly than the rest of the economy, and finally this advanced sector affects the rate of development in all other sectors (Mokyr, 1985). Restating this model in modern terms would say that first a technology emerges rapidly, then the technology matures having specific socio-economic benefits, and finally this technology becomes so disruptive that it affects all other technologies that define our socio- economic system. The first stage is marked by innovators' research, the second stage is marked by investors' forecasts, and the third stage is marked by consumers' adaptation.

Cloth weaving had been unchanged for thousands of years until flying shuttle technology emerged in 1733. This technology matured with the inventions of the spinning jenny in 1764, the power loom in 1785, and the cotton gin in 1793. By the early 1800s this collective technology was developed and became disruptive to the textile industry. Consumers preferred the high performance, low cost, and pattern options that mechanically woven fabrics provided. Hand weavers were displaced with violent opposition yet the textile revolution was evident and irrevocable (CBS News, 1997).

The difficulty of judging when and how an industrial revolution unfolds is complicated by the "failures to anticipate future development of new technologies" (Alcaly, 2003, p.66). Actually, enabling technologies can precede or follow the basic science that contains the latent potential of the industrial revolution. The striking phenomenon of failing to see latent potential is seen repeatedly over decades in the statements of some very high profile industry leaders, for example: (1) Western Union refused Alexander Graham Bell's telephone patent for just $100,000.00, insisting that the telegraph would never be replaced; (2) The British journal, *Engineering*, wrote that Thomas Edison's electric light was "unworthy of the attention of practical or scientific men" (Clarke, 1962, p. 2); (3) Thomas Watson, Chairman of IBM, stated in 1943 that he thought "there is a world market for maybe five computers" (National Research Council, 2006, p. 13); (4) Again in 1968, IBM's Advanced Computing Systems Division questioned the microchip saying *"What is it good for?"*; and (5) Ken Olson, President, Chairman, and Founder of Digital Equipment Company stated in 1977, "There is no reason anyone would want a computer in their home" (Clarke, 1962, p. 13).

Industrial revolutions are by definition benchmarks in technology that forever change the landscape of national wealth, social norms, and technical education. Alcaly (2003) points out that "we underestimate the time it took for the technologies to establish a critical standing in the economy." Dr. Joseph Bordogna, Deputy Director and Chief Operating Officer for the National Science Foundation, includes electricity, information technology, and communications as the most disruptive revolutions of the past century (Bordogna, 2003). A technology with an enormous disruptive potential usually has a long formative delay and is implemented with great difficulty and opposition. "As with information technologies, and for many of the same reasons, it took almost half a century before electric power had a significant impact on productivity growth" (Alcaly, 2003, p. 68). Hughes (2001, p. 15) also identifies electricity as a major component of the Second Industrial Revolution and further explains the reason why technological determinism stalls: "While correctly anticipating momentous changes, they frequently erred in anticipating the nature of those changes although they thought their predictions were value-free, they unwittingly imposed their values upon the technological future."

Perhaps it was the delayed impact of electrification that shadowed its significance as perhaps the greatest enabling technology of all time. Initially, most of the power increases took place in cities and "it took until 1956 for farm homes to have the same percentage of electric service (98 percent) as non-farm homes" (Milham & Ossiander, 2000, p. 1). In explaining why electrification took so long, Alcaly (2003, p. 68) writes that "Electrification of American homes and industry did not gather 'real momentum' until after World War I, when central generating capacity expanded widely and rates fell substantially, reflecting advances that had been made in producing electric power, extensive construction of new generating plants, and scale economics."

The correlation between technologies and industrial revolutions is certain but fixing causation can be problematic. More complex yet is defining cause and effect relationships between education and industrial revolutions. There has been much debate as to whether industrial revolutions expose the effectiveness of education or the serious lack of it. Nanotechnology is entering the marketplace at an ever-increasing pace. As of March 8, 2006, the Project on Emerging Nanotechnologies had counted 212 product lines that use nanotechnology.

What Emerging Nanotechnologies Will Redefine the Oklahoma Workforce?

In a report on essential nanotechnology studies, the Center for Responsible Nanotechnology indicated "that a tenfold improvement (one order of magnitude) is sufficient for a new product or method to displace existing ones" (Phoenix, 2003, p. 43). New companies that manufacture products in a "nanofactory" will greatly exceed the tenfold criterion and would displace existing companies that are not quick to change. This reflects the disruptive nature of nanotechnology on businesses, the workforce, and the economy, especially with manufactured products (Phoenix, 2003). For this reason, "push strategies" for small businesses and nano start-ups should be encouraged. "Push strategies" involve governments at all levels offering small nano businesses of 8-10 persons with useful technical assistance that addresses environmental, health, or safety issues and possibly financial support (Rejeski, 2005). If small nano businesses cannot sustain the financial burden of risk and capital investment overhead, then most start-ups may not market their own products. They will seek large company partners who can utilize their nanotech developments to improve existing commercial products (Davies, 2005). A common problem is that many large companies do not want to talk openly about their nanotechnology involvements. These companies do not want to put their resources and assets at risk with uncertainties concerning public reaction and government regulatory intentions (Rejeski 2005).

Any industry involved in R&D will need a long-term view and patience to develop a roadmap for their involvement in nanotechnology. For example, in 1947 when the transistor was developed, its cost was known, but it would have been impossible at that time to predict the cost of that transistor within an integrated circuit containing thousands of transistors in the year 2001. Predicting the actual cost of devices, circuits, and networks fabricated at the nano scale several decades from now is impossible, but like the transistor, it will likely be low enough for mass production. Because very few small start-ups or even large companies can afford to spend decades pursuing future bonanzas without near-term profits, universities and national laboratories need to provide the interdisciplinary research to establish the groundwork for the most profound breakthroughs in nanoscale technology. This type of research and partnerships are not what most universities currently foster ("Small Wonders, Endless Frontiers," 2002).

There is good reason for Oklahoma to make changes since the state's economy has grown slowly compared to neighboring states. Salehezadeh and Kickham (2002, p. 2) stated in a gnosis report for the Oklahoma Department of Human Services that while employment has been growing in Oklahoma at the 11th highest rate nationally, “the highest proportion of employment is in low-paying jobs.” The top three employment sectors in Oklahoma are services (38%), retail trade (19%), and manufacturing (13%). The services sector is first in employment but near the bottom in average weekly wages because these jobs require little or no formal training or education. Manufacturing is third in employment and also third in average weekly wages, preceded only by mining jobs and public service jobs (transportation, communication, utilities). Within an eight-state region, Oklahoma is next to last in college degrees and households with computers and internet access. Oklahoma also falls below the national average in technology and education. It is no wonder that over the last decade the purchasing power of the average worker in the two largest Oklahoma counties has decreased. According to the gnosis report, Oklahoma has “failed to adapt, to evolving economic imperatives.” The report references Peter Drucker who as early as 1969 began urging the anticipation of “knowledge workers” in a postindustrial society. The report concludes that “investment in education and training would therefore appear to be a strategy worth considering, as would strategies that improve capital productivity (Salehezadeh & Kickham, 2002, p. 1). The Oklahoma Nanotechnology Initiative may be the very strategy for improving productivity and increasing real income for the workforce by increasing the number of “knowledge workers” in the state.

How Will Nanotechnology Impact Strategic Planning for the Oklahoma Business Community?

Since only 22 percent of business professionals are well informed about nanotechnology, perhaps it is not surprising that less than 20 percent of them are making any adjustments to their strategic business plans for the coming nanotechnology impact. When the business professionals were asked if they evaluate emerging technologies for strategic planning, over 50 percent agreed that they were proactive. At this time it is apparent that nanotechnology has not been one of the emerging technologies that they include. This will likely change in the future since a high percentage of business professionals are interested in learning more about nanotechnology, and 74 percent agree that nanotechnology will have a significant impact on the Oklahoma economy.

When Oklahoma business professionals are asked about nanotechnology hiring decisions, the neutral responses rise to nearly 50 percent. This may be attributed to the modest 22 percent who are well informed about nanotechnology. The 22 percent who see a pending need to increase both the nano technologist and the non scientific workforce create a significant concern to plan for workforce training.

When business professionals were asked about their attitudes in the face of potentially negative nanotech situations, the neutral responses were again the majority of percentages. Most may feel that they are just not well enough informed to make a sound judgment. Of those who did make a decision, most of them disagreed that regulation or negative public perception would change their business. The group was about split over the issue of diminished competition without changes to the nanotech revolution. This could clearly reflect the attitude of how nanotechnology may impact different industry categories.

The attitudes toward investing in nanotechnology seem very positive in Oklahoma with very few in disagreement. A much higher percentage of business professionals are willing to invest in a nanotech start-up business than the percentage of them that are well informed about the technology. This may indicate that positive public perception is more influential for investment than actual knowledge about the science.

What Reforms Are Needed To Integrate Nanotechnology into America’s Educational Institutions?

Historically, when the security or economy of the United States has been threatened, leaders have responded with successful educational reforms. After World War II, President Franklin D. Roosevelt commissioned a team to review and recommend reforms that were needed in scientific research and education for the future well-being of our country. Only a decade later, the Soviet Union launched the first earth-orbiting satellite, and America responded with unprecedented educational reform in science and mathematics, focused on developing youthful talent in science and engineering (Jackson, 2004).

Following these educational reforms in the 1940s and 1960s, the National Commission on Excellence in Education in the 1980s again urged reform for science education in its report called, *"A Nation at Risk."* Educators then took a hard look at what had been passing for science education and began making commitments to do things differently (NSF Award ESI-9730727, 2000). Despite these efforts, a quiet crisis was developing in the United States with a rapidly growing imbalance between supply and demand of technically skilled workers that threatened to jeopardize the nation's leadership position and security. According to the BEST (Building Engineering and Science Talent) report, "the same wheels are being re-invented and the same mistakes made on a daily basis in every part of the country" (Jackson, 2004, p. 5).

Due to poor forecasting of America's need for scientists and engineers, the National Science Foundation's credibility was put in question by Rep. Howard Wolpe, Chairman of the Subcommittee on Investigations and Oversight of the House Committee on Science, Space, and Technology. NASA's administration also testified before the House Science Committee that not only was NASA disadvantaged in competing for technical talent but confirmed the general competitive problems due to a lack of scientists and engineers (Teitelbaum, 2002).

The NSF Award ESI-9730727 (2000) concluded that integrated science is a valuable and viable educational reform alternative because:

- Integration engages a greater diversity of students
- Integration presents the unifying concepts and principles of science
- Integration reflects the reality of the natural world
- Integration encourages comprehensive thinking about a complex world.

Integrated science unifies concepts and principles of science, making science seem relevant and connected to life. Project-based problem solving blurs the boundaries of the sciences and encourages students to investigate a range of disciplines and concepts based on the student's "need to know." Answering "why" and "how" questions about broad themes and unifying principles provides a rich context for a creative learning experience.

Another pedagogy for student-focused learning is "design education." Design education involves students in the process and methods of realizing an engineering artifact. This integrated and interactive education provides students with the hands-on design-build-operate experience to understand engineering concepts (Vest, 1995). Sheppard and Jenison (1996), writers for the *International Journal of Engineering,* concluded that students should understand the "how to" of generating design specifications, going from design specifications to final artifact, establishing objectives and criteria, investigating alternatives, synthesizing, analyzing, constructing, testing, and evaluating. The Accreditation Board for Engineering and Technology (ABET) requires engineering students to accomplish a major and meaningful integrated engineering design experience that brings together the fundamental concepts of mathematics, basic sciences, the humanities and social sciences, and communication skills.

In his position as Subcommittee Chairman of Nanoscience, Engineering and Technology (NSET) of the National Science and Technology Council (NSTC) and Senior Advisor for Nanotechnology, National Science Foundation, Dr. M. C. Roco urges unifying science and education by integrating research and education. In his *"The Future of the National Nanotechnology Initiative"* presentation to the NSET, Roco states that systemic changes are needed to make every laboratory a place of learning as well as research and particularly undergraduate nanotechnology education. His vision of integrated interdisciplinary or unified sciences includes "development and dissemination of new teaching modules for nanoscale science and engineering that can be used in existing undergraduate courses, particularly during first and second year studies." And to "introduce nanoscale science and technology through a variety of interdisciplinary approaches into undergraduate education, particularly in the first two collegiate years" (Roco, 2003, p. 30).

Conclusions

Nanotechnology is a catch-all word that has come to mean everything through the collective perspectives of people in multiple disciplines both technical and business, including the problem of calling things nano that are not in order to capitalize on the veiled mystery of a supercharged technology. This catch-all phenomenon is unfortunate but understandable since nanotechnology is not a product nor is it a discipline-specific application like biotechnology.

Nanotechnology is a "general purpose" technology that enhances all other technologies very much like the generation of electricity. Batteries as a source of electricity are not useful unless they are installed in a product to power the application, and the usefulness of nanotechnology is measured by the power it brings to many applications. Nanotechnology is an empowering catalyst that unlocks latent and unique properties in existing elements through molecular manipulation using scanning probe microscopy, crystalline growth, and high temperature processes. New materials that result from nanotechnology have a "general purpose" utility value for combining with other materials to optimize physical, thermal, magnetic, electrical, and optical properties or for creating devices that operate at the cellular level for biological and medical applications. Previous "general purpose" technologies (e.g., electricity generation, internal combustion, and advanced materials) have changed the very infrastructure of our country and the fabric of our society.

More of the study details, results, findings, conclusions, recommendations, and supporting documents are included in the 130-page report, "Nano Revolution: Big Impact" and it is available from steve.holley@okstste.edu. A two-year AAS degree program in "Nano-scientific Instrumentation" based on this study is being developed under a NSF ATE grant that can be reviewed at http://www.osuit.edu/academics/engineering_technologies/nanotechnology/ .

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Simulation of a Start-up Manufacturing Facility for Nanopore Arrays

Dennis W. Field

Abstract

Simulation is a powerful tool in developing and troubleshooting manufacturing processes, particularly when considering process flows for manufacturing systems that do not yet exist. Simulation can bridge the gap in terms of setting up full-scale manufacturing for nanotechnology products if limited production experience is an issue. An effective use of simulation software is identified when analyzing a typical manufacturing process flow for anodic aluminum oxide (AAO) nanopore arrays. Simulation models, using the ProModel simulation software, were developed based on production flows, projected process times, and equipment. An attempt was made to realistically estimate process times and capacities, however model outputs, in terms of quantitative values, were found less important than the activities involved in setting up the models. The ability of simulation to help link theory and practice in the classroom may be useful in leading students toward higher levels of intellectual behavior as educators strive to build students' abilities to apply, analyze, evaluate, and create, rather than simply to remember and understand.

Manufacturing Simulation

Simulation is a powerful tool in developing and troubleshooting manufacturing processes, particularly when considering process flows for manufacturing systems that do not yet exist. As noted by Mebrahtu, Walker, and Mileham (2004, p. 245): "The lack of clear understanding of the dynamics and interaction of components of modern manufacturing systems calls for the use of simulation as an essential support tool." Simulation can bridge the gap in terms of setting up full-scale manufacturing for nanotechnology products when limited production experience is an issue. Rohrer (1997) also supports the notion that simulation provides one of the best methods of validating system design if the manufacturing system being modeled does not yet exist.

This project involved an analysis of a typical manufacturing process flow for anodic aluminum oxide (AAO) nanopore arrays. Models using the ProModel simulation software were developed based on production flows, projected process times, and equipment. Boundary values for process flows, times, and equipment capacities were derived from discussions with nanotechnology researchers and from reading published reports (Argonne National Laboratory, 2004; Ba & Li, 2000; Hu, Gong, Chen, Yuan, Saito, Grimes, & Kichambare, 2001; Jessensky, Müller, & Gösele, 1998; Knaack, Redden, & Onellion, 2004; Liang, Chik, Yin, Xu, 2002; Nam, Seo, Park, Bae, Nam, Park, & Ha, 2004; Nasirpouri, Ghorbani, Irajizad, Saedi, Nogaret, 2004; Zhang, Chen, Li, & Saito, 2005). Regarding quantitative values, however, model outputs were found less important than the activities involved in setting up the models, as powerful "what if" capability in the software allows process times, capacities, and yields to be easily updated.

Background

Nanotechnology refers to applications involving products or materials with one or more features in the one to one-hundred nanometers range. For comparative purposes, most individual atoms are between one-tenth and one-half of a nanometer in diameter.

Initially, the technologies and process flows involved in the production of AAO nanopore arrays are discussed. These arrays offer cost-effective approaches to create nanoscale features over large areas, and they can be applied to the development and production of other nanotechnology devices, including sensors, memory devices, and filtration and flow membranes.

The base simulation model is then defined, and the advanced simulation software is explored including, among other things, the impact of equipment downtimes, alternative process flows based on variable attributes, and IF-THEN-ELSE operation logic, custom graphics, and costs.

The successful scale up of manufacturing for nanoscale structures and devices is not an easy task. In a report published by the Oak Ridge National Laboratory titled "Nanoscale Science, Engineering and Technology Research Directions," the authors observed that: "This linking from molecular interactions to nanostructures to functional systems is a fundamental challenge of the first order, both scientifically and technologically" (n.d. p.70).

Research in nanotechnology is well underway; however, commercial manufacturing operations for nanotechnology products are just beginning to emerge. For example, Thomas Swan & Co announced the United Kingdom's first commercial manufacturing process for high-purity single-wall carbon nanotubes in April 2004 (AZoNano, 2005).

Anodic Aluminum Oxide Nanopore Arrays

Several products associated with developing technologies were investigated and one, AAO nanopore arrays, was selected around which to develop a manufacturing flow simulation model. AAO nanopore arrays are hexagonally ordered pores fabricated from aluminium using electrochemical processing. The pores can have diameters from 12 nm to 0.1 μm and depths in excess of 60 μm. The pore diameters are controlled by the choice of anodizing voltage and electrolyte. Nanopore arrays can be used to create nanoscale features over large areas, and they can be applied in the development and production of other nanotechnology devices. The potential to use these arrays as a springboard technology to enable cost-effective development of other devices makes them particularly valuable. The process flow for AAO nanopore arrays (see Figure 1) is well documented in a number of previously referenced journal articles and abstracts describing, with some variation, the array fabrication.

Using the references, a generic example of an AAO array fabrication process involving the following steps was developed. A flowchart of the process is shown in Figure 2. It should be noted that for purposes of the simulation, process times were important, but other process specifications (for example, solution type, temperature, anodizing voltage, and concentrations) did not play a role in the analysis and were not included. More specific process details can be found in the reference list.

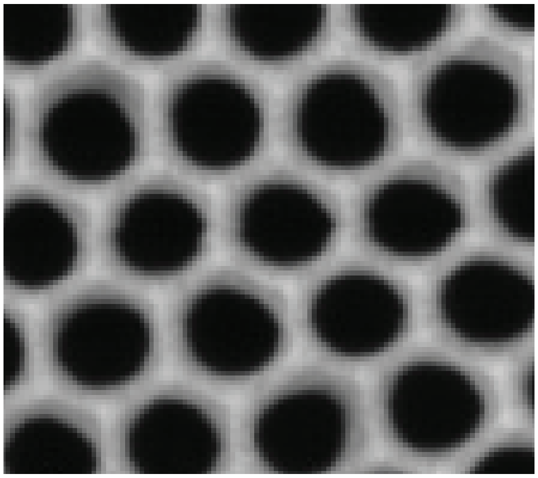

Figure 1. AAO Template. The Pore Diameter is Approximately 75 nm at 200,000 Magnification

1. Prepare the substrate. Possible options include aluminium foil, or glass substrates coated with either (a) molybdenum or (b) indium tin oxide and aluminium films. Subsequent process flow is dependent on the type of substrate, and these options are reflected in the software simulation.

2. Clean the substrate surface. This could include using a simple solvent or, for some types of substrates, an electropolish.

3. Oxidize the aluminium at a constant voltage in an oxalic acid solution at low temperature for approximately 21 hours.

4. Remove the initial anodic oxide layer—parts of which are typically distorted—by dipping in an acid mixture at an elevated temperature for 20 hours. This yields a textured pattern of concave depression on the aluminium surface.

5. Complete a second anodization of the textured aluminium for approximately 20 minutes. Use the same experimental conditions as the first anodization. This process results in the ordered holes (seen in Figure 1) fabricated from each concave depression.

6. Remove the bottom part of the anodic porous alumina membrane by etching it in solution for a short period of time (less than one minute) to form a through-hole membrane.

Simulation Software

The AAO process flow served as a vehicle to explore various simulation software capabilities. The model included "locations," which were used to identify and define specific pieces of equipment and buffers, that is "entities" used to define the various products to be processed, and "resources" that covered human resources involved in the process flows. Eleven pieces of equipment and three buffer queues were defined. The equipment included a distribution station to

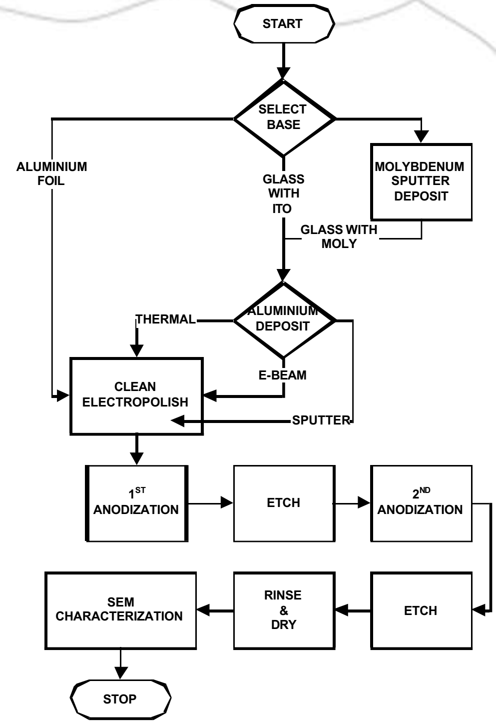

Figure 2. AAO Process Flow

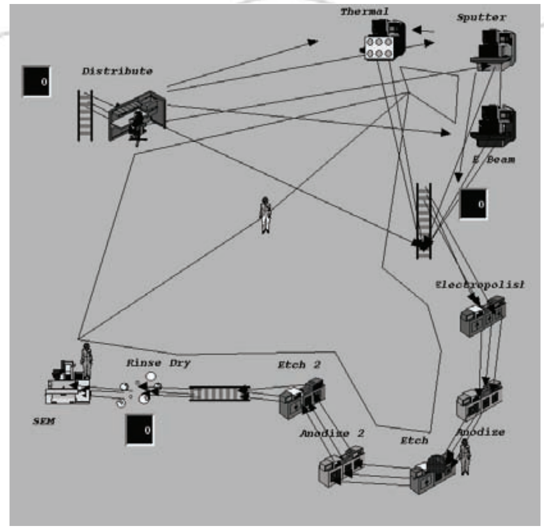

Figure 3. Simulation Model of AAO Nanopore Array Fabrication

initiate the process flow, three metallization systems (thermal, sputtering, and e-beam), an electropolish station, two anodization and two etch stations, a cleaning station, and a scanning electron microscope. The three entities created to model the three substrates used in this simulation were glass, glass with a thin film of indium tin oxide, and aluminum foil. The three resources included two production operators and one repair and maintenance (R&M) technician. Processing times input to the model ranged from a minimum of one minute for the second etch process to 21 hours for the first anodization. As it turns out, the buffers were not needed during the simulation because the arrival times of the various substrates exceeded the cycle time of the longest process (first anodization); however, it was thought that they might be useful in the future if arrival or processing times or capacities would change. Multiple graphics for the same entity were used to indicate changes in state; that is, as the substrates moved through the manufacturing process flow, the graphic was changed to reflect the various stages of completion of the part. The following advanced simulation software capabilities were analyzed: (a) the impact of equipment downtimes, (b) alternative process flows based on variable attributes, and (c) IF-THEN-ELSE operation logic, costs, and custom graphics. An example of the basic simulation model is shown in Figure 3. Equipment, resources, buffers, and resource and process paths can be seen in the model.

Results

Equipment Downtime

Downtime was associated with three pieces of equipment during their operation. The sputtering system was subject to random usage downtime with a normal distribution, N(_ = 40 hr, _ = 5 hr), simulating unexpected equipment failure, while both the e-beam evaporator and the thermal evaporator experienced clock downtimes—at 100 hours and 20 hours respectively—simulating scheduled periodic maintenance. In all cases, a repair and maintenance technician was assigned to bring the equipment back to working order. The repair time distributions for the sputtering system and the e-beam evaporator were normally distributed, N(_ = 120 min, _ = 30 min) and N(_ = 60 min, _ = 10 min) respectively. The repair time distribution for the thermal evaporator was input as a triangular distribution, T(30 min, 75 min, 90 min). The output statistics showed a 0.30 percent downtime associated with the sputtering system. The R&M technician was “used” on average 245 times during a 4,000-hour simulation. Since the e-beam was serviced every 100 hours, the technician visited it 40 times during the simulation. The thermal evaporator required service every 20 hours, or 200 times on average during a simulation. The usage of the sputtering system was estimated as follows: Approximately 53 indium tin oxide parts were processed, and 50 percent of these parts required 3 hours in the sputtering system during a simulation run. Approximately 54 glass parts were processed, and 50 percent of these parts required 4 hours in the sputtering system during a simulation run. Together, these two parts required approximately

188 hours of sputtering time over the course of a 4,000-hour simulation. Since the sputtering system went down on average every 40 hours of operation, it was reasonable for it to require service 5 times over the course of this simulation (188/40 = 4.7) for a total of 245 service calls to the R&M technician for the three machines.

Alternative Process Flows

Multiple numbered routes were established with operation logic statements defining which route entities would follow. This action took place at the glass distribution and glass sputter process steps. An attribute was set to 1, 2, or 3 according to a user-defined distribution in which 50 percent of the parts were assigned a 1, 30 percent of the parts were assigned a 2, and 20 percent of the parts were assigned a 3. Once the attribute was set, the part was processed according to a unique set of operation logic statements. Using IF-THEN-ELSE operation logic, entities received differing processing instructions including route, processing time, and entity graphic based on entity attributes and user-defined distributions. This action also took place at the glass distribution and sputter process steps. For example, if the attribute = 1, the processing time in the sputtering system was 4 hours, the entity graphic was switched to state 3, and the entity went directly to the pre-etch queue from the sputtering system (Route 3). Additionally, the counter for parts having both molybdenum and aluminum sputtered was incremented by one. The counters were enabled through the use of variables. Variables were set up to count the number of parts being processed through the three metallization systems (sputtering, e-beam, and thermal). Six variables were represented: (1) a molybdenum film coated with sputtered aluminum, (2) a molybdenum film coated with aluminum deposited using an e-beam evaporator, (3) a molybdenum film coated with aluminum deposited using a thermal evaporator, (4) an indium tin oxide film coated with sputtered aluminum, (5) an indium tin oxide film coated with aluminum deposited using an e-beam evaporator, and (6) an indium tin oxide film coated with aluminum deposited using a thermal evaporator. As a part passed through one of the metallization systems, the related variable was incremented by one. Counters displayed the running totals during the simulation.

Costs

Location costs, resource costs, and entity costs were entered into the model. Data entry was straightforward and took very little time. Again, considering that each of these costs may vary significantly depending on the characteristics of the facilities and processes being modeled, the final outputs were judged less important than the model-building process.

Custom Graphics

Rather than creating multiple entities for each state change, an entity can have multiple graphics that may be invoked as part of an operation statement. This yields a more realistic simulation, as a person can "build" the graphic much as he or she builds the product as it flows through the process. Multiple graphics were used for all the products simulated. The four graphics associated with the glass substrate were as follows: Graphic 1 represents a bare glass substrate; Graphic 2 represents the glass substrate with a thin film of molybdenum added to the glass surface. Graphic 3 indicates that an aluminum film has been added to the molybdenum-coated substrate, and Graphic 4 is the finished form with the aluminum film converted to an AAO film following the anodization process.

Summary

All planned learning objectives were accomplished with this project. Apart from spending significant time working through the Training Workbook (ProModel Corporation, 2003) and the User Guide (ProModel Corporation, 2004) for the simulation software, only one difficulty was encountered and not resolved. Initially, the model was intended to have one anodization station and one etch station. The material was to flow from one to the other and then return for a second cycle; however, once material progressed to the etch station, it was blocked from returning to the anodize station by a subsequent incoming part, and the part at the anodization station was blocked from moving to the etch station by the part waiting to return to the anodization station. There were no apparent easy ways to schedule cyclical activity among locations using the "Move Logic," so additional anodization and etch stations were created. Once that conflict was resolved, the model ran well.

Implications for Technology Programs

Using simulation software is a well advised practice for students studying manufacturing methods. In terms of advanced manufacturing and the manufacture of emerging products—for example, in the nanotechnology field—the software is an excellent vehicle to encourage students and others to learn in detail the equipment, people, and processes involved in operations. Additionally, in many technology programs learning objectives related to manufacturing best practices have been added to the curricula. Ultimately, simulation offers students the opportunity in a classroom setting to better understand the relationship between theory and practice in each of these areas. Researchers can consider where and how improvements in product and process flows can impact a variety of key metrics. Metrics, such as cycle time, costs, and efficiencies in equipment and labor, can be investigated and observed as changes are made to the model. Bottlenecks can be located and tracked. The ability of simulation to help link theory and practice may be useful in leading students toward higher levels of intellectual behavior. Educators should strive to build students' abilities to apply, analyze, evaluate, and create, rather than simply to remember and perhaps understand. Simulation has a role to play in helping build these abilities.

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Bio-based Nanocomposites: An Alternative to Traditional Composites

Jitendra S. Tate, Adekunle T. Akinola, and Dmitri Kabakov

Abstract

Polymer matrix composites (PMC), often referred to as fiber reinforced plastics (FRP), consist of fiber reinforcement (E-glass, S2-glass, aramid, carbon, or natural fibers) and polymer matrix/resin (polyester, vinyl ester, polyurethane, phenolic, and epoxies). E-glass/polyester and E-glass/vinyl ester composites are extensively used in the marine, sports, transportation, military, and construction industries. These industries primarily use low-cost open molding processes, such as manual/spray lay-up. Polyester and vinyl ester resin systems produce styrene emissions. Because of the stringent EPA regulations on styrene emissions, composite manufacturers are interested in using low-cost closed molding processes, such as vacuum-assisted resin transfer molding (VARTM) and styrene-free resin systems such as non-foam and full-density polyurethanes (PUR). Polyurethanes are polymers created by addition of polyisocyanates and polyols. The polyol component in polyurerhane can be produced from soybean oil. This study demonstrates that with the proper addition of nanoparticles, mechanical properties of soy-based polyurethane can be enhanced. These nanomodified soy-based polyurethane/glass composites manufactured by using the low-cost VARTM process provide alternatives to traditional glass/polyester and glass/vinyl ester composites. These composites will be more environmental friendly for two reasons: (a) Polyurethane does not produce styrene emission, thereby, resulting in a safer work place and (b) Polyol is made from a renewable resource (soybean oil).

Introduction

Composite materials are everywhere in our daily lives. Many products on the market contain composite materials or structures, such as plywood, golf clubs, canoes, and coated knives. Although the term *composite* is very broad and refers to the combination of two or more materials at the macroscopic level, this article refers to a composite as a fiber-reinforced plastic (FRP) or polymer matrix composite (PMC). Reinforcement typically is fibers and the matrix is a thermoset resin. Polymer matrix is most commonly referred to as resin. In about 90 percent of these composites fiberglass is used for reinforcement, and either polyester or vinyl ester is used as a matrix. The open molding technique is used for 65 percent of the composites manufactured, whereas the remaining 35 percent of the composites are manufactured through closed molding. In open molding, materials are exposed to the atmosphere during the fabrication, whereas in closed molding, materials are closed in a two-sided mold or in a vacuum bag. Figures 1-4 display popular applications of PMCs. Figure 1 shows a small house built using glass fiber-reinforced phenolic sandwich composites panels. These DURA-SIP™ composite panels are strong, lightweight, fire resistant, UV light resistant, and impervious to water, mold, and insects (DuraSip, 2009). Figure 2 is an illustration of a boat made of glass fiber-reinforced composite (Solemar, Inc., 2009). Figure 3 shows wind turbine blades made of glass reinforced composites (ENERCON GmbH, 2009). PMCs, especially those that are glass reinforced, dominate the wind turbine blade market because of their superior fatigue resistance characteristics, high specific stiffness, and ability to be made into complex shapes. As shown in Figure 4, Boeing uses high performance carbon fiber-reinforced composites for the fuselage section of its new 787 Dreamliner (Boeing, 2009).

The method used in this research, vacuum-assisted resin transfer molding (VARTM) is a closed molding process. VARTM uses vacuum pressure to infuse resin into fibers. This method can reduce styrene emissions to the open air. Styrene is a volatile organic compound (VOC), and its emission is restricted by EPA regulations in the composites industry (U.S. Government Printing Office, 2009).

Figure 1. Small House Built Using Sandwich Composites (DuraSip, 2009)

Figure 2. Boat Made of Glass Fiber Reinforced Composite (Solemar, Inc., 2009)

Figure 3. Wind Turbine Blades (ENERCON GmbH, 2009)

Figure 4. Boeing 787 Fuselage (Boeing, 2009)

Most of the resins used for composites are petroleum based; however, some of them can be replaced by environmentally friendly materials, such as soy-based polyurethane. In general, such natural materials have inferior properties when compared to traditional petroleum-based materials. Polymer nanocomposites consist of polymeric materials and reinforced nanoscale materials (nanoparticle). The nanoparticle has at least one dimension in a nanometer scale. Polymer nanocomposites show major improvements in mechanical properties, gas barrier properties, thermal stability, and fire retardancy (Koo, 2006).

Researchers have used different nanoparticles, for example, nanoclays, predispersed nanosilica, nanoalumina, multi-wall carbon nanotubes (MWCNT), carbon nanofibers (CNF), nano SiC particles, and HNT™ (Halloysite Nanotubes), in liquid thermoset resins to enhance mechanical/thermal properties (Akinyede, Kelkar, Mohan, & Sankar, 2009; Chisholm, Jeelani, Mahfuz, Rangari, & Rodgers, 2004; Grimmer & Dharan, 2009; Karapappaset, Kostopoulos, Tsotra, & Valounliotis, 2009; Manjunatha, Kinloch, Sprenger, & Taylor, 2009; Xu & Vas, 2008; Ye, Chen, Wu, & Ye, 2004; Zhou, Pervin, & Jeelani, 2007; Njuguna, Alcock, & Pielichowski, 2007). Some of these nanoparticles such as MWCNT and CNF are expensive, and their use in large-scale composites production is limited. Nanoclays are inexpensive, but their dispersion in liquid thermoset resins is a challenge. A typical method used for nanoclay dispersion in liquid thermoset is high shear mixing. Implementation of such a method on a large scale is expensive and adds processing cost. These researchers propose to use low-cost halloysite nanotubes (HNT) that are naturally available. It can be dispersed uniformly using simple centrifugal mixing (Tate, Adenkunle, Patel, & Massingill, 2009). Researchers have shown remarkable improvement in mechanical performance by adding HNT to composites, as discussed in the section on HNT.

The composites industry is very large, approaching $25 billion per year. America maintains a leading position globally in composites manufacturing and research. Biobased nanocomposites are the future of this industry; therefore, this topic should capture the attention of both professionals and the general public.

Thermoset Polyurethane Resin

Polyurethanes (PUR) are thermoset products with the addition of polyisocyanates and polyols. PUR is a tough polymer useful in coatings, structural foams, and composites. Polyols can be fossil oil based or, vegetable oil based. Through this research, we suggest the feasibility of using a soybean oil-based polyol as a component of PUR composites.

Applications and Properties of PUR Composites

Polyurethanes have been used extensively mainly because they exhibit excellent abrasion resistance, toughness, low temperature flexibility, chemical and corrosion resistance, and a wide range of mechanical strength. Two-component polyurethane (2K-PUR) systems are especially attractive because they offer flexibility in formulation, which enables customization for demanding end-use requirements.

Polyurethane can be used to produce various forms—from flexible to rigid structures—with negligible emission. PUR foam composites have been used primarily for automotive interior and exterior parts, such as pickup truck boxes, load floors, package shelves, and inner door panels. Non-foamed, full-density PUR composite systems are beginning to be used for applications such as window lineal, bathtubs, electric light poles, and large parts for trucks and off-road vehicles (Sherman, 2006). The following are the major advantages of PUR composites.

1. Composites manufactured from PUR resins have superior tensile strength, impact resistance, and abrasion resistance compared with composites based on unsaturated polyester and vinyl ester resins (Connolly, King, Shidaker, & Duncan, 2005, 2006).

2. Cure times are much faster than for polyester spray-up—about 20 minutes versus 2 to 4 hours in non-automotive applications (Sherman, 2006).

3. They contain no styrene and therefore do not generate large amounts of VOCs.

Soy-based Polyurethane

In recent years, there has been interest in developing materials and products based on bio-based resources. The principal drivers for this include environmental, regulatory, and economical factors. A recent study indicates that soy-based polyols have a 25 percent lower total environmental impact compared to petroleum-based polyols; the use of soy polyols will result in reductions in net CO2 contributions to global warming, smog formation, ecological toxicity, and fossil fuel depletion (Pollock, 2004).

Soy-based polyol has been mainly used in coatings, adhesives, sealants, and foams. Mannari and Massingill (2006) investigated soy-based polyols used in coating applications. However, few attempts have been made to use it in reinforced composites. Dwan'Isa, Misra, and Drzal (2004) have reported that, bio-based polyurethane from soybean oil-derived polyol and diisocyanate on reinforcement with glass fibers adds significantly to the mechanical properties of the base resin. Thermogravimetric analysis (TGA) shows the improved thermal stability of the bio-based polyurethane with the reinforcement of glass fiber. Husic, Javni, and Petrovic (2005) illustrated that mechanical properties (such as tensile and flexural strength, tensile and flexural modulus of soypolyol-based composites) were comparable to composites based on a petrochemical polyol. They futher indicated that because soy-based polyurethanes offer better thermal, oxidative, and hydrolytic stability compared to petrochemical-based polyurethanes, they could become a viable alternative to the petrochemical urethane matrix resins for composites. In this research, soybean oil-based polyol was supplied by Arkema, Inc. under trade name Vikol®-1. The aliphatic polyisocynate component was petroleum based, and it was supplied by Bayer Material Science, Inc. under the trade name Desmodur® Z4470BA. The addition of soy-based polyol and polyisocynate in proper proportion will result in thermoset soy-based polyurethane resin.

Nanomodifications of Soy-based Polyurethane

The introduction of inorganic nanoparticles as additives into polymer systems results in polymer nanocomposites (PNC). When such a nanomodified polymer is used to make a reinforced composite, it is called "reinforced polymer nanocomposite." In this research, soy-based polyurethane was modified using Halloysite nanotubes (HNT).

Halloysite Nanotubes (HNT™)

HNT are naturally formed in the Earth over millions of years by the surface weathering of aluminosilicate materials and are composed of aluminum, silicon, hydrogen, and oxygen. Halloysite nanotubes are ultra-tiny hollow tubes (diameters typically are smaller than 100 nm (10-7 m) and lengths typically range from about 0.5 to 1.2 microns). The functional characteristics desired for specific applications can be controlled through the selection of the diameter and the length of the HNT. These diameters typically range from about 40 nm to 200nm, and they come in a variety of lengths, allowing for a wide range of applications. Halloysite nanotubes can be coated with metallic and other substances to achieve a wide variety of electrical, chemical, and physical properties (NaturalNano, Inc, 2009). HNT technology is abundant and inexpensive; its polar surface can be readily modified. It is a potential alternative to expensive carbon nanotubes for nanocomposites, when mechanical properties are concerned (Ye et al., 2007).

Researchers and engineers have investigated Halloysite as an excellent polymer modifier because of the properties associated with it. Halloysite is a useful constituent of many polymeric composites for the purpose of mechanical and thermal improvement, including those where the polymer is a coating like polyurethane, a film, a molded part, fiber, foam, or even in a copolymer (Li, Liu, Ou, Guo, & Yang, 2008). Monomer is a simple compound that can be joined to form long chain-like structures called polymers. Copolymers are polymers that consist of two or more monomers.

Ye et al. (2007) found that the morphology of the HNT was geometrically similar to multi-walled carbon nanotubes. These researchers blended epoxy with HNT in different loadings of 0.8, 1.6, and 2.3 wt percent. The results demonstrated that blending epoxy with 2.3 wt percent HNT increased the impact strength by four times without scarifying flexural modulus, strength, and thermal stability.

In the last 3-4 years, researchers have reported improvement in mechanical and thermal properties for thermoplastics nanocomposites and elastomeric nanocomposites using HNT (Li et al., 2008; Ye et al., 2007). However, there are very few attempts made to use HNT in reinforced composites. In this research, soy-based polyurethane is modified using HNT with different loadings.

Experimentation

Full-density polyurethane was modified using HNT nanoparticles. This nanomodified polyurethane was used to manufacture E-glass reinforced composites using the low-cost vacuum assisted resin transfer molding (VARTM) process. The composites were mechanically characterized in compression, flexure, and interlaminar shear loading.

Material system

Table 1 displays the material system for glass-reinforced composites. E- glass woven roving fabrics (Rovcloth® 1854) was supplied by Fiberglas Industries, Inc. Soy-based polyol (Vikol®-1) was manufactured and supplied by Arkema, Inc. Aliphatic polyisocynate (Desmodur® Z4470BA) was supplied by Bayer, Inc. Aliphatic polyisocynate has better resistance to ultraviolet (UV) radiation. HNT were supplied by NaturalNano, Inc. Soy-based polyol and polyisocynates were mixed in a 1:1 equivalent ratio to produce non-foam and full- density thermoset polyurethane resin. Dibutyltin dilaurate (DBTL) was used as a catalyst. . Three different loadings of HNT 0.8, 1.6, and 2.4 wt percent were used in making composite panels.

Table 1. Material System of Bio-based Nanocomposites

Material	Brand Name, Description
Reinforcement	Rovcloth® 1854, E-glass woven roving
Nanoparticle	Untreated HNT
Polyol	Vikol®-1, Soybased polyol
Isocynate	Desmodur® Z4470BA, aliphatic polyisocynate
Catalyst	Dibutyltin dilaurate (DBTL)

Dispersion of Nanoparticles

Uniform dispersion of nanoparticles in liquid polymer is essential for improvement in mechanical/thermal properties. Planetary centrifugal mixers (THINKY® Model ARE-250) had successfully been used by Air Force Research Lab (AFRL) researchers to effectively disperse carbon nanofibers without damage in the liquid polymers for EMI applications (Air Force Reseach Laboratory, 2007). These mixers also can be used to de-gas due to fast centrifugal motion. In this research, the THINKY® Model ARV-310 was used for dispersion and degassing. HNT were dispersed in soy-based polyol using the THINKY mixer for three minutes at 2000 rpm without vacuum. To this nanomodified polyol was added aliphatic polyisocynate in a 1:1 equivalent ratio. This mixture was run through the THINKY mixer maintaining 28.5” vacuum for one minute at 2000 rpm for degassing.

There is always suspicion about the health hazards while handling dry nanoparticles. Nanoparticles can be easily absorbed into the body either through the skin or by inhaling them because of their small size. Special care must be taken when handling and storing dry nanoparticles. According to protocol, dry nanoparticles are not handled in open air. Containers are stored and opened only in a glove box and premixed with liquid resin and then transported for further processing. When nanoparticles are mixed in liquid resin they impose less harm.

VARTM manufacturing process

The VARTM process is an attractive and affordable method of fabricating composite products. It can produce high-quality complex and large-scale components. As shown in Figure 5, a complex structural aerospace part was produced using the VARTM process by V System Composites (V System Composites, 2009). Figure 6 shows a huge and complex boat hull being manufactured using VARTM (Advanced Projects Group, 2009). The major requirement of a resin system for VARTM is that the viscosity should be in the range of 100 to 1000 cP in order for the resin to flow throughout the fabric. Viscosity plays a major role in the VARTM process.

Figure 5. Complex 3D Structural Aerospace Part (V System Composites, 2009)

During the VARTM manufacturing process, dry fabric is placed into a tool and vacuum bagged in conjunction with the resin distribution line, the vacuum distribution line, and the distribution media. A low viscosity resin is drawn into the fabric through the aid of a vacuum. Resin distribution media ensures resin infiltration in

Figure 6. Huge Boat Hull Manufactured Using VARTM (Advanced Projects Group, 2009)

the thickness direction of composite panels. The key to successful resin infiltration of the fabric is the design and placement of the resin distribution media which allows complete wet-out of the fabric and eliminates voids and dry spots. Properly designed and properly placed resin distribution media eliminate “race tracking” and resin leakage around the fabric (Seemann, 1990, 1994). Figure 7 ilustrates how different bagging materials are laid in the VARTM process (Tate, 2004). Figure 8 explains the step-by-step process of laying different bagging materials.

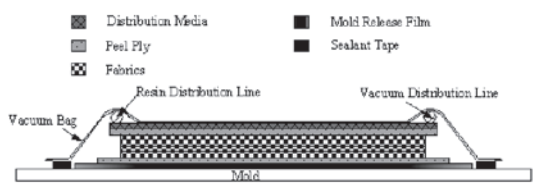

Figure 7. Schematic of the VARTM Process

Figure 8. VARTM Process at Small Scale - from Material Arrangement to Resin Infusion and Demolding

The soy-based polyol had a room temperature viscosity of 780cP. There was no considerable increase in viscosity with 0.8 wt percent loading of HNT. Viscosity increased to 1080 cP with 2.4 wt percent of HNT loading. The composites panels of 300mm _ 200mm size with 8 layers of E-glass woven roving were produced using VARTM at room temperature. The panels were kept in a mold for 24 hours (green cure), followed by post cure at room temperature for seven days and then another cure at 120 ºC for three hours. The overall fiber percentage of VARTM manufactured composites was found to be 53 percent. Water-jet cutting of the composite was used to ensure minimal damage at the edges of the panels.

Mechanical Testing

Earlier research indicates that mechanical properties of soy-based polyurethane/E-glass composites are quite comparable to traditional polyester/E-glass and vinyl ester/E-glass composites (Tate, Massingill, Patel, Rikka, & Arabie, 2007; Tate, Massingill, Patel, & Konga, 2008). Table 2 summarizes the results.

Results and Discussion

Table 3 displays average mechanical properties of HNT-modified PU/E-glass composites. For 0.8 wt percent loaded HNT modified composites, flexural strength and modulus were increased by 6 percent and 28 percent, respectively. ILSS, a measure of fiber/matrix adhesion, improved by 82 percent with this loading. UCS decreased with increases in wt percent loading of HNT. UCS decreased by 8 percent for 0.8 wt percent loading. Overall, 0.8 wt percent loading of HNT showed considerable improvement in overall performance of composites.

Table 2. Properties of E-Glass/Vinyl Ester; E-glass/Biobased PU; and E-Glass/Polyester

Property	Rovcloth® 1854	Rovcloth® 1854	Rovcloth® 1854
	E-glass woven roving/vinyl ester (Shivakumar, 2006)	E-glass woven roving/biobased PU (Tate et al., 2007, 2008)	E-glass woven roving/polyester (Fiber Glass Industries, 2009)
V_f	60	40	40
UTS, MPa	512.5	385.4	267.5
E, GPa	29.2	20.82	22.2
v_{xy}	0.16	-	0.17

Note: V_f – Fiber Volume Percentage; UTS – Ultimate Tensile Strength; E – Tensile Modulus; v_{xy} in-plane Poisson's ratio

Interlaminar shear strength (ILSS) and compressive strength are matrix dominant properties. Flexural properties are also affected by matrix material. The major interest of this study was to evaluate the effect of nanomodifications of matrix on matrix-dominant properties of composites. Therefore, ILSS, compressive strength, flexural strength, and flexural modulus of nanomodified composites were evaluated.

Five specimens in each category were tested. Compression tests were performed according to ASTM D 6641/D 6641M titled "Standard Test Method for Determining the Compressive Properties of Polymer Matrix Composite Laminates Using a Combined Loading Compression (CLC) Test Fixture" to evaluate compressive strength. Flexure tests were performed according to ASTM D 790-92 entitled "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials" to evaluate flexural strength and modulus. Short-Beam tests were performed according to ASTM D 2344/D 2344M entitled "Standard Test Method for Short-Beam strength of Polymer Matrix Composite Materials and their Laminates" to evaluate interlaminar shear strength (ILSS).

Table 3. Mechanical Properties of HNT Modified Polyurethane/E-Glass

Composites

HNT wt %	0	0.8	1.6	2.4
Vf, %	50	52	55	56
UCS (MPa)	82.6	75.7	61.29	81.28
Fs (MPa)	149.13	158.85	138.32	139.53
Ef (GPa)	9.84	12.60	11.33	10.47
ILSS (MPa)	14.28	26.00	14.36	21.86

Note: UCS – Ultimate Compressive Strength; Fs – Flexural strength; Ef – Flexural modulus; ILSS – Interlaminar shear strength

Conclusions

The addition of HNT™ in soy-based polyurethane/E-glass composites improves mechanical performance considerably. Three different loadings were studied for HNT, 0.8, 1.6, and 2.4 wt percent. Viscosity of polyurethane was observed at 780 cP for 0.8wt percent HNT, which increased to 1080 cP for 2.4wt percent HNT loading. The VARTM process was used successfully with this low-viscosity resin at room temperature. Low viscosity of nanomodified polyurethane makes it a perfect choice for the low-cost VARTM process. The vacuum planetary centrifugal mixer is an efficient, economical, and a fast method of uniformly dispersing HNT in polyol. For 0.8 wt percent loaded HNT modified composites, flexural strength, flexural modulus, and ILSS were increased by 6 percent, 28 percent, and 82 percent, respectively. ILSS is a measure of fiber/matrix adhesion. This research suggested that fiber/matrix adhesion can be improved by modifying polyurethane with HNT, which in turn improves the mechanical properties. Thus, nanomodified soy-based polyurethane/glass composites manufactured using the VARTM process provide alternatives to traditional glass/polyester and glass/vinyl ester composites. These composites will be more environmental friendly for two reasons: (a) polyurethane doesn't produce styrene emission thus making workplace safe and (b) the polyol component is made from soybean oil, which is a renewable resource.

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A Guide for the Safe Handling of Engineered and Fabricated Nanomaterials

Wanda L. Greaves-Holmes

Abstract

In the absence of scientific clarity regarding the potential health effects of occupational exposure to nanoparticles, there is a need for guidance in making decisions about hazards, risks, and controls (Schulte & Salmanca-Buentello, 2007). Presently, no guiding principles have been universally accepted for personal protective equipment that is worn to prevent exposure to nanomaterials. The purpose of this article is to survey the literature and determine if research has been completed that validates whether or not occupational exposure to nanomaterials is potentially hazardous to the health of humans.

Introduction

The science of nanotechnology is the manipulation of matter on a near-atomic scale to produce new structures, materials, and devices (NIOSH, 2005b). Nanotechnology and nanosciences are global technologies that can possibly transform the world's economy and its workforce. Work places (such as research laboratories, production or operation facilities) in which nanomaterials are engineered, processed, used, disposed of or recycled are areas of concern, because in these areas workers are initially exposed to nanomaterials.

Every aspect of nanotechnology is catching the attention of governments and business organizations worldwide. The National Science Foundation (NSF, 2007) predicts that nano-related goods and services could be a $1 trillion market in 2015 and will employ 2 million people, 1 million of which will be in the United States (Roco & Bainbridge, 2001). Saniei et al. (2007) believe nanotechnology will be one of the fastest growing industries in history, even larger than the combined telecommunications and information technology industries that started at the beginning of the technology boom in 1998.

Further, the 2008 National Nanotechnology Initiative (NNI) budget request for nanotechnology research and development was over $1.44 billion, an increase of 13 percent from 2007 (The National Science Foundation, 2009b). The growth in NNI investments during the past seven years, along with a total cumulative funding for the NNI since its inception of $8.3 billion, reflects the consistent, strong support of the United States government for nanotechnology (National Science Foundation, 2009c).

Via the universal commercialization of nanosciences, nanotechnology and nanomaterials have dramatically improved the effectiveness of more than 660 existing consumer and industrial products (Woodrow Wilson International Center for Scholars, 2009). Additionally, nanotechnology has substantially affected the growth of new applications, ranging from disease identification and management to remediation of the environment (e.g., superior drug development and expansion, extremely hard nanocoatings, water decontamination, enhanced information and communication technologies, and the production of stronger, lighter materials).

The research for this paper was conducted by summarizing information reported in scholarly, peer-reviewed journals, scientific databases, expert interviews, relevant conferences, and workshops. Other sources of information included national and international governmental and private organizations whose members research environmental health and safety regarding the workplace.

An innovative and relatively new area of research called nanotoxicology, investigates the distinctive biokinetics and toxicological potential of engineered and fabricated nanomaterials. Engineered nanomaterials are generally indentified as ultrafine particulate matter measuring between 1– 100 nm in one dimension. The tendency of these nanoparticles of different shapes (e.g., geodesic spherical domes, crystalline structures, rods, tubes), different chemistries (e.g., carbon, silicon, gold, cadmium (and other metals), possessing different surface characteristics and exhibiting distinctly different properties from their original bulk materials respectively (due to varying mass, charges, solubility, and porosity) to translocate from the location of deposit in the respiratory tract to extra pulmonary organs such as the brain, heart, liver, and bone marrow are being researched, examined, and evaluated using various multidisciplinary approaches. These findings have been anticipated. Numerous epidemiological research studies have documented that acute adverse health effects (e.g., cardiovascular disease) can be related to exposure to ambient airborne particles. Additionally, scientific investigators affirm that ill effects are associated with molecular composition and physical attributes of small particle substances. Case in point: pulmonary exposure to minute quartz particles impairs endothelium and pulmonary muscle and tissues; however, the identical particles slightly coated with clay are less detrimental to the respiratory system. Moreover, the long, thin fibers of asbestos pose a major risk to humans when inhaled. Yet, if these fibers are pulverized into tiny particles with the exact chemical composition, the danger is appreciably reduced. Scientists suggests that synthetic carbon molecules (Carbon 60 molecules also known as buckminsterfullerene, fullerene or buckyballs) have a high potential of being accumulated in animal tissue, but the molecules appear to break down in sunlight, perhaps reducing their possible environmental dangers (Purdue University, 2008).

In the October 2008 issue of ScienceDaily, a featured article highlighted a toxicology study that concluded that some types of nanomaterials (Carbon 60 molecules) can be harmful to animal cells and other living organisms (University of Calgary, 2008). Particle physics scientists and researchers of fine atmospheric pollutants, ultrafine nanoparticulate matter released in to the atmosphere can remain airborne for a significant period of time, be inhaled repeatedly, and then collect in all regions of the respiratory system with over one third of the nanoparticles being deposited in the deepest regions of the lungs. Further, investigators have discovered evidence that indicates nanoparticles can dissolve in the cell membranes, pass into cells, thereby crossing the blood–brain barrier, reform as particles, and alter the cell functions (University of Calgary, 2008).

A 2006 publication distributed by NIOSH entitled, *Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials,* states that inhalation is the most common route of exposure to airborne particles in the workplace. Inhalation is the process by which nanomaterials and oxygen in the air can be brought into the lungs and into close contact with the blood, which then absorbs it and carries it to all parts of the body. At the same time the blood gives up waste matter (such as carbon dioxide), which is carried out of the lungs when exhaled. Investigators also discovered evidence that indicates nanoparticles can dissolve in the cell membranes and pass into cells, thereby crossing the blood–brain barrier, reform as particles, and alter the cell functions (University of Calgary, 2008).

Humans have several defense methods to eradicate unwanted foreign objects. One process involves chemical decomposition for soluble particles and the other mechanism is physical translocation, (i.e., transporting particles from one place to another, for insoluble or low-solubility particles). Soluble ultrafine dusts will dissolve and will not be discussed here, because its effects are highly variable, depending on the composition of the dust. By translocation, insoluble or low-solubility particles deposited in the pulmonary system are eliminated from the respiratory system by transporting them elsewhere in the body. The mucociliary escalator eliminates the coarsest particles, which normally are deposited in the upper lungs, mainly in the tracheobronchial region. The tracheobronchial mucous membranes are covered with ciliated cells that form an escalator and expel the mucus containing the particles into the digestive system. Normally this is an efficient mechanism that eliminates particles from the respiratory tract in less than 24 hours (Kreyling et al., 2002). In the alveolar region, the macrophages will take up the insoluble particles by phagocytosis, a mechanism whereby the macrophages will surround the particles, digest them if they can, and proceed slowly to the mucociliary escalator to eliminate them. This is a relatively slow process, with a half-life of about 700 days in humans (Oberdorster, Oberdoster, & Oberdoster, 2005). However, the efficiency of phagocytosis is heavily dependent on particle shape and size.

Several studies seem to show that unagglomerated ultrafine particles deposited in the alveolar region are not phagocyted efficiently by the macrophages (particularly particles with a diameter of less than 70 nm). However, the macrophages are very efficient for coarser particles in the one to three micrometer range (Tabata and Ikada, 1988). The often inefficient uptake of ultrafine and nanometric dusts by macrophages can lead to a major accumulation of particles if exposure is continued and to greater interaction of these particles with the alveolar epithelial cells. Studies have shown that some ultrafine particles can pass through the epithelium and reach the interstitial tissues (Ferin, Oberdorster, & Penney, 1992; Kreyling & Scheuch, 2000, Kreyling et al., 2002; Borm, 2002; Borm, Schims, & Albrecht, 2004). This phenomenon seems more prevalent in higher species, such as dogs and monkeys, than it does in rodents (Kreyling & Scheuch, 2000; Nikula, Snipes, Barr, Griffith, Henderson, & Mauderly, 1997).

For the workforce, either insoluble or low-solubility nanoparticles in biological fluid are the greatest cause for concern. Due to their minuscule size, scientist have found that nanoparticles posses unique properties. Certain types of nanoparticles can pass through the body's natural defense systems and be transported through the body in insoluble form. Therefore, random nanoparticulate matter can terminate in the bloodstream after penetrating the respiratory or gastrointestinal membranes. These particles circulate to different organs and then collect at specific sites. Certain particles journey along the olfactory nerves and enter the brain, whereas other types penetrate through cell walls and reach the nucleus of the cell. These unusual characteristics could be beneficial as vectors to transmit medication to specific body systems, including the brain. The aforementioned scenario could be repeated and have a toxic effect on the health of workers not utilizing personal protective equipment (PPE.) Usually, in the field of toxicology, the detrimental effects are normally associated with the amount of the substance to which an organism, an animal, or a human is exposed. The greater the mass absorbed, the greater the effect. When investigators studied the behavior or a nanoparticle, it was evident that the measured effects are not related to the mass of the product, which contradicts the classical interpretation of toxicity measurement. Study results are unambiguous, and demonstrate that at equal mass, nanoparticles are more toxic than products of the same chemical composition but of greater size.

Although several authors found a good correlation between the specific surface and the toxic effects, a consensus seems to be emerging in the scientific community that several factors can contribute to the toxicity of nanoparticles; thus, it is currently impossible, with our limited knowledge, to weigh the significance of each of these factors or predict the precise toxicity of each new product.

According to The Institut de recherché Robert-Sauvé en santé et en sécurité du travail (IRSST, 2008), published studies link the observed effects to different nanoparticle parameters: specific surface, number of particles, size and granulometric distribution, concentration, surface dose, surface coverage, degree of agglomeration of the particles and pulmonary deposition site, the "age" of the particles, surface charge, shape, porosity, crystalline structure, electrostatic attraction potential, particle synthesis method, hydrophilic/hydrophobic character and postsynthesis modifications (grafting of organic radicals or surface coverage to prevent aggregation). The presence of certain contaminants, such as metals, can also favor the formation of free radicals and inflammation, while the chemical composition and delivery of surface components, nanoparticles colloidal and surface properties, compartmentation in the lung passages and biopersistence are other factors that add a dimension of complexity to understanding the health effects of nanoparticles and their toxicity (IRSST, 2008).

The slow dissolution of certain nanoparticles or nanoparticle components in the body can become a major factor in their toxicity. These various factors will influence the functional, toxicological, and environmental impact of nanoparticles. Several effects have already been shown in animals. Among these, toxic effects have been identified in several organs (heart, lungs, kidneys, reproductive system), as well as genotoxicity and cytotoxicity. For example, some particles cause granulomas, fibrosis, and tumoural reactions in the lungs. Thus, titanium dioxide, a substance recognized as having low toxicity, shows high pulmonary toxicity on the nanoscale in some studies and no (or almost no) effects in other studies. In general, the toxicological data specific to nanoparticles remains limited, often rendering quantitative risk assessment difficult due to the small number of studies for most substances, the short exposure periods, the different composition of the nanoparticles tested (diameter, length, and agglomeration), or the often unusual exposure route in the work environment. Additional studies (absorption, biopersistence, carcinogenicity, translocation to other tissues or organs, etc.) are necessary for quantitative assessment of the risk associated with inhalation exposure and percutaneous exposure of workers (Ostiguy, Soucy, Lapointe, Woods, Menard, & Trottier, 2008).

Although major trends could emerge that show that nanomaterials are harmless to humans, this author suggests that precautions should be established. Presently, there are no universally standardized, published guidelines or regulations for the safe handling of engineered nanomaterials. Research is inconclusive as to whether or not engineered nanoparticles may pose risk to human health because of various compositions, sizes, and ability to cross mammal's cell membranes. Engineered nanomaterials may exhibit higher toxicity due to their size compared to larger particles of the same composition. Current information about risks associated with nanoparticle exposure is limited. Until irrefutable evidence is available regarding the risks associated with nanomaterials, voluntary precautions for the workplace are highly recommended.

Risk assessments and control strategies for nanotechnology research will be based on the most current toxicological data, exposure assessments, and exposure control information available from The National Institute for Occupational Safety and Health (NIOSH), Nanosafe of the United States Environmental Protection Agency (EPA), The Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), and the National Institutes of Health (NIH), which were used to formulate these voluntary guidelines. "Approaches to Safe Nanotechnology: A Informational Exchange" published by NIOSH (2006), Nanosafe's procedures, (2008), and the European Agency for Safety and Health at Work literature (2009), suggest the following workplace practices, which may decrease the risk of human exposure to nanomaterials.

Manufacturing Controls

Strict control of airborne nanoparticles can be accomplished by using conventional capture exhaust ventilation, such as chemical fume hoods. Glove box containment is another effective method. Passing capture exhaust through a HEPA filter will provide protection against release of nanoparticles into the environment. Some actions that would require manufacturing controls include the following:

1. Working with nanomaterial in a liquid media during pouring or agitation, which could release aerosols size nanoparticles.
2. Fabricating nanoparticles.
3. Handling nanomaterials powder.
4. Maintenance or cleaning of equipment used to produce nanomaterials.

Preventing inhalation, skin exposure, and ingestion are paramount if workers are to work safely with nanomaterials. This involves following standard procedures that should be followed for any particulate material with known or uncertain toxicity. Because nanoparticles are so minute, these particles follow airstreams more easily than do larger particles. Control of airborne exposure to nanoparticles can be accomplished mainly by using engineering controls that are similar to those used for general aerosols and vapors. Nanomaterials can be easily collected and retained in standard ventilated enclosures, such as fume hoods. Additionally, nanoparticles are readily collected by HEPA filters. Respirators with HEPA filters are sufficient protection for nanoparticles in case of immense spills. Many nanomaterials are synthesized in enclosed reactors or glove boxes. These enclosures are under vacuum or exhaust ventilation, which prevent exposure during the actual synthesis. Inhalation exposure could occur during additional processing of materials removed from reactors; this processing should be done in fume hoods. In addition, maintenance on reactor parts, which could release residual particles in the air should be done in fume hoods. Another process, the synthesis of particles using sol-gel chemistry, should be carried out in ventilated fume hoods or glove boxes. Good work practices will help minimize exposure to nanomaterials. These work practices are consistent with good laboratory practices in general, for example,

1. Avoiding direct contact with nanomaterials, especially when airborne or in liquid media during a pouring and/or mixing process with a high degree of agitation.
2. Wearing FFP3 type masks or powered respirators incorporating helmets equipped with H14 high efficiency particulate air (HEPA) filters.
3. Installing and using efficient exhaust systems with particle filtration and

ventilation system filters to minimize free-flowing airborne ultrafine particles.

4. Using a sturdy glove with good integrity is imperative when working with dry, ultrafine particulate matter. Using two pairs of disposable nitrile gloves is strongly recommended.

5. Wearing protective eye wear (e.g., safety goggles).

6. Wearing protective clothing and safety shoes.

7. Utilizing ULPA filters (United Lightning Protection Association) to minimize combustion.

8. Prohibiting storage or consumption of food or drink in areas where nanomaterials are handled.

9. Prohibiting application of cosmetics, etc. in areas where nanomaterials are handled.

10. Requiring all employees to wash their hands before leaving the work area and after removing protective gloves.

11. Removing lab coats, which can easily become contaminated, before leaving the lab or workplace.

12. Making sure that workers avoid touching their face or other exposed skin after working with nanomaterials and prior to hand washing.

13. Labeling all containers with nanomaterials consistent with existing laboratory requirements.

14. Cleaning of any areas where nanomaterials could be must be done via wet wiping or HEPA vacuuming. Dry sweeping or using compressed air is prohibited.

15. Disposing of contaminated cleaning materials must comply with hazardous waste disposal policies.

Fire and Explosions

Other potential safety concerns regarding nanoparticles are fires and explosions, which can happen if large quantities of dust are generated during production. This is expected to become more of a concern when reactions are scaled up to pilot plant or production levels. Scientific evidence concludes that carbonaceous and metal dusts can burn and explode if an oxidant such as air and an ignition source are present.

Conclusion

Nanotechnology is a dynamic and rapidly growing field that offers the promise of technologically based innovations that will substantially improve the quality of life for all humans. The preliminary data currently available on some products reveals that engineered nanoparticles must be handled with care and that workers' exposure must be minimized, because effects from such particles are extremely variable from one product to another. Therefore, a comprehensive understanding of the possible drawbacks of nanotechnology is critical to realizing the significant benefits of nanotechnology. The majority of the initial nanomaterials research has focused on the probable hazards and risks of nanotechnology-based manufacturing. Although, toxicological research for nanotechnology is in its formative years, concerns about potential risks to the health and safety of workers will require definitive answers.

Researchers' questions should be focused on manufacturing practices, procedures, and controls for the present and future uses of nanotechnology. Yet another area of interest is the environment. What is the fate of the environment when nanomaterials are disposed? What does "appropriate" disposal mean as it relates to the field of nanotechnology? What is obvious; however, is that the nanotechnology manufacturing industry must identify, develop, and implement an optimum approach for protecting both its employees and the public at large. One promising option indicates that researchers may be able to "engineer out" unacceptable levels of toxicity in nanomaterials. If this undertaking comes to fruition, then the industry will be able to minimize the potentially negative implications to its workers and the environmental impact of nanomaterial-based manufacturing and products.

According to the documents previously reviewed, toxic effects on living organisms as well as the unique physicochemical characteristics of nanomaterials validate the immediate use of personal protective equipment, etc. to limit exposure and protect the health of potentially exposed individuals. The introduction of strict universally standardized guidelines and procedures to prevent any risk of occupational disease in researchers, students, or workers who synthesize, transform, or use nanoparticles should be introduced *immediately*. A scientific approach to the identification, assessment, and mitigation of the risks posed by nanomaterial manufacturing and commercialization will protect the public, the environment, and industry, thereby ensuring that the benefits of nanotechnology are shared by all.

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Potential Ambient Energy-Harvesting Sources and Techniques

Faruk Yildiz

Abstract

Ambient energy harvesting is also known as energy scavenging or power harvesting, and it is the process where energy is obtained from the environment. A variety of techniques are available for energy scavenging, including solar and wind powers, ocean waves, piezoelectricity, thermoelectricity, and physical motions. For example, some systems convert random motions, including ocean waves, into useful electrical energy that can be used by oceanographic monitoring wireless sensor nodes for autonomous surveillance. Ambient energy sources are classified as energy reservoirs, power distribution methods, or power-scavenging methods, which may enable portable or wireless systems to be completely battery independent and self sustaining. The students from different disciplines, such as industrial technology, construction, design and development and electronics, investigated the effectiveness of ambient energy as a source of power. After an extensive literature review, students summarized each potential ambient energy source and explained future energy-harvesting systems to generate or produce electrical energy as a support to conventional energy storage devices. This article investigates recent studies about potential ambient energy-harvesting sources and systems.

Introduction

Today, sustaining the power requirement for autonomous wireless and portable devices is an important issue. In the recent past, energy storage has improved significantly. However, this progress has not been able to keep up with the development of microprocessors, memory storage, and wireless technology applications. For example, in wireless sensor networks, battery-powered sensors and modules are expected to last for a long period of time. However, conducting battery maintenance for a large-scale network consisting of hundreds or even thousands of sensor nodes may be difficult, if not impossible. Ambient power sources, as a replacement for batteries, come into consideration to minimize the maintenance and the cost of operation. Power scavenging may enable wireless and portable electronic devices to be completely self-sustaining, so that battery maintenance can be eventually removed. Researchers have performed many studies in alternative energy sources that could provide small amounts of electricity to electronic devices, and this will be explained in another section of this article.

Energy harvesting can be obtained from different energy sources, such as mechanical vibrations, electromagnetic sources, light, acoustic, airflow, heat, and temperature variations. Energy harvesting, in general, is the conversion of ambient energy into usable electrical energy. When compared with energy stored in common storage elements, such as batteries, capacitors, and the like, the environment represents a relatively infinite source of available energy.

Systems continue to become smaller, yet less energy is available on board, leading to a short run-time for a device or battery life. Researchers continue to build high-energy density batteries, but the amount of energy available in the batteries is not only finite but also low, which limits the life time of the systems. Extended life of the electronic devices is very important; it also has more advantages in systems with limited accessibility, such as those used in monitoring a machine or an instrument in a manufacturing plant used to organize a chemical process in a hazardous environment. The critical long-term solution should therefore be independent of the limited energy available during the functioning or operating of such devices. Table 1 compares the estimated power and challenges of various ambient energy sources in a recent study by Yildiz, Zhu, Pecen, and Guo (2007). Values in the table were derived from a combination of published studies, experiments performed by the authors, theory, and information that is commonly available in textbooks. The source of information for each technique is given in the third column of the table. Though this comparison is not comprehensive, it does provide a broad range of potential methods to scavenge and store energy from a variety of ambient energy sources. Light, for instance, can be a significant source of energy, but it is highly dependent on the application and the experience to which the device is subjected. Thermal energy, in contrast, is limited because temperature differences across a chip are typically low. Vibration energy is a moderate source, but again, it is dependent on the particular application, as cited by Torres and Rincon-Mora (2005).

- Human Body: Mechanical and thermal (heat variations) energy can be generated from a human or animal body by actions such as walking and running;

Table 1. Comparison of Power Density of Energy Harvesting Methods

Energy Source	Power Density & Performance	Source of Information
Acoustic Noise	0.003 µW/cm3 @ 75Db 0.96 µW/cm3 @ 100Db	(Rabaey, Ammer, Da Silva Jr, Patel, & Roundy, 2000)
Temperature Variation	10 µW/cm3	(Roundy, Steingart, Fréchette, Wright, Rabaey, 2004)
Ambient Radio Frequency	1 µW/cm2	(Yeatman, 2004)
Ambient Light	100 mW/cm2 (direct sun) 100 _W/cm2 (illuminated office)	Available
Thermoelectric	60 _W/cm2	(Stevens, 1999)
Vibration (micro generator)	4 _W/cm3 (human motion—Hz) 800 _W/cm3 (machines—kHz)	(Mitcheson, Green, Yeatman, & Holmes, 2004)
Vibrations (Piezoelectric)	200 µW/cm3	(Roundy, Wright, & Pister, 2002)
Airflow	1 µW/cm2	(Holmes, 2004)
Push buttons	50 _J/N	(Paradiso & Feldmeier, 2001)
Shoe Inserts	330 µW/cm2	(Shenck & Paradiso, 2001)
Hand generators	30 W/kg	(Starner & Paradiso, 2004)
Heel strike	7 W/cm2	(Yaglioglu, 2002) (Shenck & Paradiso, 2001)

Ambient Energy Sources

Ambient energy harvesting, also known as energy scavenging or power harvesting, is the process where energy is obtained and converted from the environment and stored for use in electronics applications. Usually this term is applied to energy harvesting for low power and small autonomous devices, such as wireless sensor networks, and portable electronic equipments. A variety of sources are available for energy scavenging, including solar power, ocean waves, piezoelectricity, thermoelectricity, and physical motions (active/passive human power). For example, some systems convert random motions, including ocean waves, into useful electrical energy that can be used by oceanographic monitoring wireless sensor nodes for autonomous surveillance.

The literature review shows that no single power source is sufficient for all applications, and that the selection of energy sources must be considered according to the application characteristics. Before going into details, a general overview of ambient energy sources are presented, and summarized the resources according to their characteristics:

- Natural Energy: Wind, water flow, ocean waves, and solar energy can provide limitless energy availability from the environment;

- Mechanical Energy: Vibrations from machines, mechanical stress, strain from high-pressure motors, manufacturing machines, and waste rotations can be captured and used as ambient mechanical energy sources;

- Thermal Energy: Waste heat energy variations from furnaces, heaters, and friction sources;

- Light Energy: This source can be divided into two categories of energy: indoor room light and outdoor sunlight energy. Light energy can be captured via photo sensors, photo diodes, and solar photovoltaic (PV) panels; and

- Electromagnetic Energy: Inductors, coils, and transformers can be considered as ambient energy sources, depending on how much energy is needed for the application.

Additionally, chemical and biological sources and radiation can be considered ambient energy sources. Figure 1 shows a block diagram of general ambient energy-harvesting systems. The first row shows the energy-harvesting sources. Actual implementation and tools are employed to harvest the energy from the source are illustrated in the second row. The third row shows the energy-harvesting techniques from each source. The research efforts are employed by the above listed sources to explore in general how practical devices that extract power from ambient energy sources are. A broad review of the literature of potential energy-scavenging methods has been carried out by the authors. The result of this literature review is categorized for each source, and follows in the next few sections of this paper.

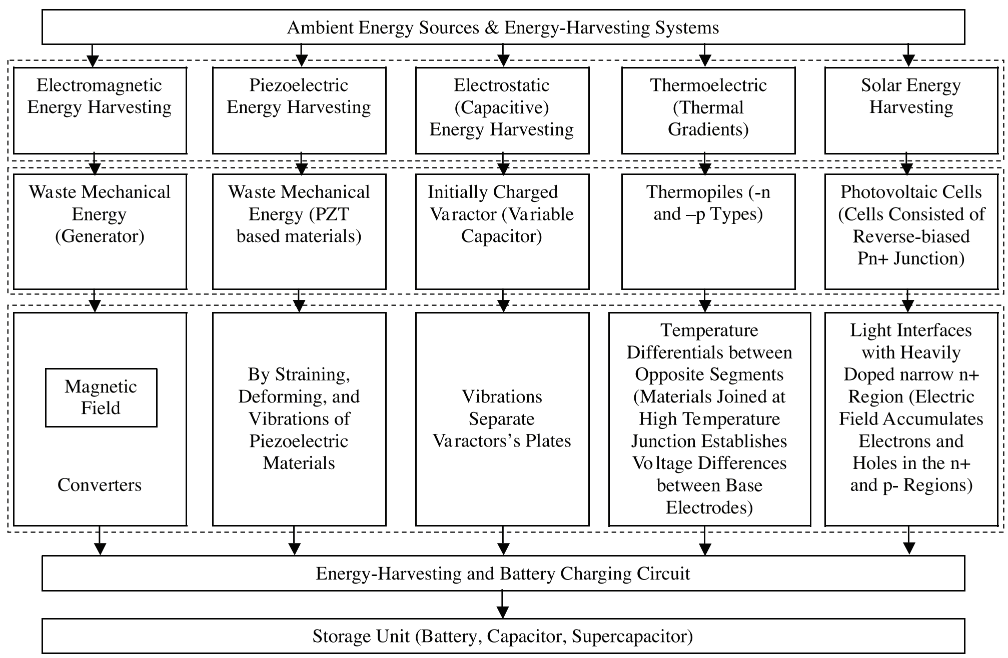

Figure 1. Ambient Energy Systems

Mechanical Energy Harvesting

An example of electric power generation using rotational movement is the self-powered, battery-less, cordless wheel computer mouse cited by Mikami, Tetsuro, Masahiko, Hiroko (2005). The system is called Soc and is designed as an ultra low power wireless interface for short-range data communication as a wireless battery-less mouse. The system was designed uniquely to capture rotational movements by the help of the mouse ball to generate and harvest electric power. The electric generator is powered through exploiting rolling energy by dragging the mouse. The energy-harvesting system was intended to power the electronic system of a mouse device, such as the ultra low power RF transmitter and microcontroller. The experimental results of the study showed that the mouse only needed 2.2mW energy to operate. The total energy captured using an energy-harvesting system was bigger than 3mW, which was enough for the wireless mouse operations in a transmit range of one meter.

Another example of mechanical energy harvesting is an electrets-based electrostatic micro generator, which was proposed by Sterken, Fiorini, Baert, Puers, and Borghs (2003). In this system, a micro machined electrostatic converter consisted of a vibration sensitive variable capacitor polarized by an electret. A general multi domain model was built and analyzed in the same study, and it showed that power generation capabilities up to 50µw for a 0.1cm^2 surface area were attainable.

Mechanical Vibrations

Indoor operating environments may have reliable and constant mechanical vibration sources for ambient energy scavenging. For example, indoor machinery sensors may have plentiful mechanical vibration energy that can be monitored and used reliably. Vibration energy-harvesting devices can be either electromechanical or piezoelectric. Electromechanical harvesting devices, however, are more commonly researched and used. Roundy, Wright, and Rabaey (2004) reported that energy withdrawal from vibrations could be based on the movement of a spring-mounted mass relative to its support frame. Mechanical acceleration is produced by vibrations that, in turn, cause the mass component to move and oscillate. This relative dislocation causes opposing frictional and damping forces to be applied against the mass, thereby reducing and eventually extinguishing the oscillations. The damping force energy can be converted into electrical energy via an electric field (electrostatic), magnetic field (electromagnetic), or strain on a piezoelectric material. These energy conversion schemes can be extended and explained under the three listed subjects because the nature of the conversion types differs even if the energy source is vibration. In the section below, the main differences of the three sources are discussed.

Electromagnetic

This technique uses a magnetic field to convert mechanical energy to electrical energy (Amirtharajah & Chandrakasan, 1998). A coil attached to the oscillating mass is made to pass through a magnetic field, which is established by a stationary magnet, to produce electric energy. The coil travels through a varying amount of magnetic flux, inducing a voltage according to Faraday's law. The induced voltage is inherently small and therefore must be increased to become a viable source of energy. (Kulah & Najafi, 2004). Techniques to increase the induced voltage include using a transformer, increasing the number of turns of the coil, or increasing the permanent magnetic field (Torres & Rincón-Mora, 2005). However, each of these parameters is limited by the size constraints of the microchip as well as its material properties.

Piezoelectric

This method alters mechanical energy into electrical energy by straining a piezoelectric material (Sodano, Inman, & Park, 2004). Strain or deformation of a piezoelectric material causes charge separation across the device, producing an electric field and consequently a voltage drop proportional to the stress applied. The oscillating system is typically a cantilever beam structure with a mass at the unattached end of the lever, which provides higher strain for a given input force (Roundy & Wright, 2004). The voltage produced varies with time and strain, effectively producing an irregular AC signal on the average. Piezoelectric energy conversion produces relatively higher voltage and power density levels than the electromagnetic system. Moreover, piezoelectricity has the ability of some elements, such as crystals and some types of ceramics, to generate an electric potential from a mechanical stress (Skoog, Holler, & Crouch, 2006). This process takes the form of separation of electric charge within a crystal lattice. If the piezoelectric material is not short circuited, the applied mechanical stress induces a voltage across the material. There are many applications based on piezoelectric materials, one of which is the electric cigarette lighter. In this system, pushing the button causes a spring-loaded hammer to hit a piezoelectric crystal, and the voltage that is produced injects the gas slowly as the current jumps across a small spark gap. Following the same idea, portable sparkers used to light gas grills, gas stoves, and a variety of gas burners have built-in piezoelectric based ignition systems.

Electrostatic (Capacitive)

This method depends on the variable capacitance of vibration-dependent varactors. (Meninger, Mur-Miranda, Amirtharajah, Chandrakasan, & Lang, 2001). A varactor, or variable capacitor, which is initially charged, will separate its plates by vibrations; in this way, mechanical energy is transformed into electrical energy. Constant voltage or constant current achieves the conversion through two different mechanisms. For example, the voltage across a variable capacitor is kept steady as its capacitance alters after a primary charge. As a result, the plates split and the capacitance is reduced, until the charge is driven out of the device. The driven energy then can be stored in an energy pool or used to charge a battery, generating the needed voltage source. The most striking feature of this method is its IC-compatible nature, given that MEMS (Micro-electromechanical system) variable capacitors are fabricated through relatively well-known silicon micro-machining techniques. This scheme produces higher and more practical output voltage levels than the electromagnetic method, with moderate power density.

In a study conducted to test the feasibility and reliability of the different ambient vibration energy sources by Marzencki (2005), three different vibration energy sources (electrostatic, electromagnetic, and piezoelectric) were investigated and compared according to their complexity, energy density, size, and encountered problems. The study is summarized in Table 2.

Table 2. Comparison of Vibration Energy-Harvesting Techniques

	Electrostatic	Electromagnetic	Piezoelectric
Complexity of process flow	Low	Very High	High
Energy density	4 mJ cm-3	24.8 mJ cm-3	35.4 mJ cm-3
Current size	Integrated	Macro	Macro
Problems	Very high voltage and need of adding charge source	Very low output voltages	Low output voltages

Thermal (Thermoelectric) Energy Harvesting

Thermal gradients in the environment are directly converted to electrical energy through the Seebeck (thermoelectric) effect, as reported by Disalvo (1999) and Rowe (1999). Temperature changes between opposite segments of a conducting material result in heat flow and consequently charge flow since mobile, high-energy carriers diffuse from high to low concentration regions. Thermopiles consisting of n- and p-type materials electrically joined at the high-temperature junction are therefore constructed, allowing heat flow to carry the dominant charge carriers of each material to the low temperature end, establishing in the process a voltage difference across the base electrodes. The generated voltage and power is relative to the temperature differential and the Seebeck coefficient of the thermoelectric materials. Large thermal gradients are essential to produce practical voltage and power levels (Roundy, Wright, & Rabaey, 2004). However, temperature differences greater than 10°C are rare in a micro system, so consequently such systems generate low voltage and power levels. Moreover, naturally occurring temperature variations also can provide a means by which energy can be scavenged from the environment with high temperature. Stordeur and Stark (1997) have demonstrated a thermoelectric micro device, which is capable of converting 15 _W/cm^3 from 10 °C temperature gradients. Although this is promising and, with the improvement of thermoelectric research, could eventually result in more than 15 _W/cm^3, situations in which there is a static 10 °C temperature difference within 1 cm^3 are, however, very rare, and assume no losses in the conversion of power to electricity.

One of the latest designs of thermoelectric energy harvester is the thermoelectric generator (TEG) designed and introduced by Pacific Northwest National Laboratory (2007). This new thermoelectric generator is used to convert environmental (ambient) thermal energy into electric power for a variety of applications that necessitates low power use. This thermoelectric energy harvester includes an assembly of very small and thin thermocouples in a unique configuration that can exploit very small (>2°C) temperature variations that are occurring naturally in the environment of the application such as ground to air, water to air, or skin to air interfaces. The body of the TEG consisted of reliable and stable components that provided maintenance free, continuous power for the lifetime of the application claimed by the manufacturer. Depending on the temperature range, the TEG's electrical output can be changed from a few microwatts to hundreds of milliwatts and more by modifying the design. Applications of this energy-harvesting design are diverse, including automotive performance monitoring, homeland and military security surveillance, biomedicine, and wilderness and agricultural management. It is also documented that the thermoelectric energy harvester may be appropriate for many other stand-alone, low-power applications, depending on the nature of the application.

In addition to PNNL's patent-pending thermoelectric generator, Applied Digital Solutions Corporation has developed and presented a thermoelectric generator as a commercial product (PNNL, 2007). This thermoelectric generator is capable of producing 40mw of power from 5 ∞C temperature variations using a device that is 0.5 cm^2 in area and a few millimeters thick (Pescovitz, 2002). This device generates about 1V output voltage, which can be enough for low- power electronic applications. Moreover, the thermal-expansion-actuated piezoelectric generator has also been proposed as a method to convert power from ambient temperature gradients to electricity by Thomas, Clark and Clark (2005).

Pyroelectricity Energy Harvesting

The "pyroelectric effect" converts temperature changes into electrical voltage or current (Lang, 2005). Pyroelectricity is the capability of certain materials to generate an electrical potential when they are either heated or cooled. As a result of the temperature change, positive and negative charges move to opposite ends through migration (polarized) and thus, an electrical potential is established. Pryroelectric energy-harvesting applications require inputs with time variances which results in small power outputs in energy-scavenging applications. One of the main advantages that pyroelectric energy harvesting has over thermoelectric energy harvesting is that most of the pyroelectric materials or elements are stable up to 1200 ∞C or more. Stability allows energy harvesting even from high temperature sources with increasing thermodynamic efficiency.

Light Energy (Solar Energy) Harvesting

A photovoltaic cell has the capability of converting light energy into electrical energy (Kasap, 2001; Raffaelle, Underwood, Scheiman, Cowen, Jenkins, Hepp, Harris, & Wilt, 2000). Each cell consists of a reverse biased pn+ junction, in which the light crosses with the heavily conservative and narrow n+ region. Photons where the light energy exists are absorbed within the depletion region, generating electron-hole pairs. The built-in electric field of the junction immediately separates each pair, accumulating electrons and holes in the n+ and p regions, respectively, establishing an open circuit voltage. With a load connected, accumulated electrons travel through the load and recombine with holes at the p-side, generating a photocurrent that is directly proportional to the light intensity and independent of the cell voltage. Several research efforts, have been conducted so far have demonstrated that photovoltaic cells can produce sufficient power to maintain a micro system. Moreover, a three-dimensional diode structure constructed on absorbent silicon substrate helps increase efficiency by significantly increasing the exposed internal surface area of the device (Sun, Kherani, Hirschman, Gadeken, & Fauchet, 2005). Overall, photovoltaic energy conversion is a well-known integrated circuit compatible technology that offers higher power output levels, when compared with the other energy-harvesting mechanisms. Nevertheless, its power output is strongly dependent on environmental conditions; in other words, varying light intensity.

Acoustic Noise

Acoustic noise is the result of the pressure waves produced by a vibration source. A human ear detects and translates pressure waves into electrical signals. Generally a sinusoidal wave is referred to as a tone, a combination of several tones is called a sound, and an irregular vibration is referred to as noise. Hertz (Hz) is the unit of sound frequency; 1 Hz equals 1 cycle, or one vibration, per second. The human ear can perceive frequencies between 20 Hz and 20 000 Hz. Acoustic power and acoustic pressure are types of acoustic noise. Acoustic power is the total amount of sound energy radiated by a sound source over a given period of time, and it is usually expressed in Watts. For acoustic pressure, the reference is the hearing threshold of the human ear, which is taken as 20 microPa. The unit of measure used to express these relative sound levels is the Bel or decibel (1 Bel equals 10 decibels). The Bel and decibel are logarithmic values that are better suited to represent a wide range of measurements than linear values (Rogers, Manwell, & Wright, 2002).

Rare research attempts have been made of harvesting acoustic noise from an environment where the noise level is high and continuous, to transfer it into electrical energy. For example, a research team at the University of Florida examined acoustic energy conversion. They reported analysis of strain energy conversion using a flyback converter circuit (Horowitz et al. 2002). The output of a vibrating PZT piezoceramic beam is connected to an AC to DC flyback converter, which is estimated to provide greater than 80 percent conversion efficiency at an input power of 1 mW and 75% efficiency at an input power of 200 μW (Kasyap, Lim, et al. 2002). It was finalized that there is far too insufficient amount of power available from acoustic noise to be of use in the scenario being investigated, except for very rare environments with extremely high noise levels.

Human Power

Researchers have been working on many projects to generate electricity from active/passive human power, such as exploiting, cranking, shaking, squeezing, spinning, pushing, pumping, and pulling (Starner & Paradiso, 2004). For example some types of flashlights were powered with wind-up generators in the early 20th century (US patent 1,184,056, 1916). Later versions of these devices, such as wind-up cell phone chargers and radios, became available in the commercial market. For instance, Freeplay's (a commercial company) wind-up radios make 60 turns in one minute of cranking, which allows storing of 500 Joules of energy in a spring. The spring system drives a magnetic generator and efficiently produces enough power for about an hour of play.

A battery-free wireless remote control for Zenith televisions was another human-powered device. The design, called "Space Commander", was introduced by Robert Adler in 1956. The system consisted of a set of buttons that hit aluminum material to produce ultrasound. The produced ultrasound energy was decoded at the television to turn it on, change channels and mute the volume (Adler, Desmares, & Spracklen, 1982). Adler's "Space Commander" design was then replaced by the active infrared remote controls and is being used in many current remote control systems.

Another similar architecture, developed by Paradiso and Feldmeier (2001) is a piezoelectric element, which was comprised of a resonantly matched transformer and conditioning electronics. This system was actuated when hit by a button, and it produced about 1mJ at 3V per 15N push. The generated power was enough to run a digital encoder and radio that was able to transmit over 50 feet. Materials used for this device were off-the-shelf components, which enabled placing compact digital controllers independently without any battery or wire maintenance.

An average human body burns approximately 10.5 MJ every day, which is equal to about 121W of power dissipation. Power dissipation occurs in the average human body either actively or passively in daily life motions, making the human body and motions an attractive ambient energy source. Researchers have proposed and conducted several studies to capture power from the human body. For example Starner has researched and investigated some of these energy- harvesting techniques to power wearable electronics (Starner, 1996). MIT researchers considered these studies and suggested that the most reliable and exploitable energy source occurs at the foot during heel strikes when running or walking (Shenck & Paradiso, 2001). This research initiated the development of piezoelectric shoe inserts capable of producing an average of 330 µW/cm2 while an average person is walking. The first application of shoe inserts was to power a low power wireless transceiver mounted to the shoe soles. The ongoing research efforts mostly focused on how to get power from the shoe, where the power is generated, to the point of interest or application. Such sources of power are considered as passive power sources in that the person is not required to put extra effort to generate power because power generation occurs while the person is doing regular daily activities, such as walking or running. Another group of power generators can be classified as active human-powered energy scavengers. These types of generators require the human to perform an action that is not part of the normal human performance. For instance, Freeplay has self-powered products that are powered by a constant-force spring that the user must wind up to operate the device (FreePlay Energy, 2007). These types of products are very useful because of their battery-free systems.

For an RFID (Radio frequency identification) tag or other wireless device worn on the shoe, the piezoelectric shoe insert offers a good solution. However, the application space for such devices is extremely limited, and as mentioned previously, they are not very applicable to some of the low-powered devices, such as wireless sensor networks. Active human power, which requires the user to perform a specific power-generating motion, is common and may be referred to separately as active human-powered systems (Roundy, 2003).

Conclusion

In conclusion, several currently developed, and overlooked ideas and options exist, and these can provide new energy resources to portable or wireless electronics devices within the energy-harvesting systems. The possibility of overall dependence on ambient energy resources may remove some constraints required by the limited reliability of standard batteries. Ambient energy harvesting can also provide an extended lifespan and support to conventional electronics systems. Students involved in this paper learned different ambient energy-harvesting, conversion, and storage systems. Students agreed to start a new research identify various ambient energy sources and design unique energy-harvesting systems.

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Technology Transfer Issues and a New Technology Transfer Model

Hee Jun Choi

The following are major issues that should be considered for efficient and effective technology transfer: conceptions of technology, technological activity and transfer, communication channels, factors affecting transfer, and models of transfer. In particular, a well-developed model of technology transfer could be used as a framework for facilitating a technology transfer process. There are many popular models of technology transfer; examples include the appropriability model, the dissemination model, the knowledge utilization model, the contextual collaboration model, the material transfer model, the design transfer model, and the capacity transfer model (Rogers, 2003; Ruttan & Hayami, 1973; Sung & Gibson, 2005; Tenkasi & Mohrman, 1995). According to the appropriability model, purposive attempts to transfer technologies are unnecessary, because good technologies sell themselves. Regarding the dissemination model, the perspective is that transfer processes can be successful when experts transfer specialized knowledge to a willing recipient. The knowledge utilization model emphasizes strategies that effectively deliver knowledge to the recipients. A contextual collaboration model is based on the constructivist idea that knowledge cannot be simply transmitted, but it should be subjectively constructed by its recipients. The material transfer model focuses on the simple transfer of new materials, such as machinery, seeds, tools, and the techniques associated with the use of the materials. According to the design transfer model, transfer of designs, such as blueprints and tooling specifications, should accompany the technology itself for effective technology transfer. The capacity transfer model emphasizes the transfer of knowledge, which provides recipients with the capability to design and produce a new technology on their own.

These models were developed and used to make technology transfer successful. A successful transfer of technology, however, might not be guaranteed simply by using a particular model. In addition, the previously mentioned models of technology transfer tend to be fragmented rather than integrated. This implies that a new model of technology transfer should be developed that includes novel and macro viewpoints. Accordingly, this article will propose a new integrated model of technology transfer that reflects recipients' perspectives by considering the key components for enhancing technology transfer. In order to achieve this purpose, this paper first focused on understanding implications that are necessary to identifying the main components for effective technology transfer by reviewing and analyzing the main issues related to technology transfer.

Technology Concepts, Technological Activity, and Technology Transfer

Defining technology is paramount because it helps to identify phenomena related to technology transfer. Since the 1960s, many scholars have tried to understand the real meaning of technology using different underlying philosophies (DeVore, 1987; Frey, 1987; Galbraith, 1967; Mitcham, 1980; Skolimowski, 1966). The definitions or meanings of technology these authors proposed were unique, according to their context, philosophy, economy, or other variables. This implies that it might not be that simple to define technology because technology is situation and value specific. However, the concept of technology should be outlined in order to understand what is being transferred in a technology transfer process. Two approaches have been used to comprehend technology: one is to define technology in a way of capturing the platonic essence in a few sentences by differentiating technology from science, and the other is to provide characterizations of technology. Scholars, such as Skolimowski (1966), Galbraith (1967), and DeVore (1987) might be the representatives of the former approach. Skolimowski (1966) defined technology as a form of human knowledge and a process of creating new realities. He argued that science is concerned with what is, but technology is concerned with what is to be. Later, Galbraith (1967) defined technology as the systematic application of scientific or other organized knowledge to practical tasks. This definition is notable because it emphasizes the systematic and practical aspects of technology. DeVore (1987), a major scholar, made an effort to define technology. He argued that technology should create the human capacity to "do," and it should be used to create new and useful products, devices, machines, or systems. He also emphasized the relationship between technology and social purpose. He contended that technology has always been situated directly in the social milieu and conditioned by values, attitudes, and economic factors; thus, the goal of technology is the pursuit of knowledge and know-how for specific social ends.

In contrast, some scholars criticized defining technology in a few sentences. They argued for providing characterizations of technology. Frey (1987) could be considered the most typical advocator of this approach. In 1987, he characterized technology as four elements: object, process, knowledge, and volition. Technology as object is regarded as the concept of physical embodiments, involving tools, machines, consumer products, instruments, or any objects that have intentionally been created to extend practical human possibilities. Moreover, technology as an object may be tangible and focused on efficiency. Technology as process is concerned with how to use or develop the object effectively. From the systems perspective, technology as process would be a means to improve the system's performance. Skolimowski (1966) also supported this knowledge viewpoint when he stated that technology is a form of human knowledge. According to Mitcham (1980), volition, which incorporates aims, intentions, desires, and choices, provides links to tie together the three aspects of technology: object, process, and knowledge. All technologies are influenced by human intention. In other words, when, how, and why technology will be used depends on human intention and will. Consequently, technology as volition emphasizes the human element and culture within technology.

According to DeVore (1987), the range of technological activity includes everything from problem identification to the design and implementation of solutions. This involves not only technical or physical elements but also human elements. Savage and Skerry (1990) argued that the ultimate outcome of technological activity is the solution derived from the problem-solving activity undertaken by humans through the use of technological processes and resources. The model of technology activity that Johnson, Gatz, and Hicks (1997) proposed seems to be based on the open-systems model composed of inputs, transformations, outputs, environment, and feedback. Their model consists of inputs, personal problem solving environment, outputs, and impacts of social context. They regarded the ultimate outcome of a technology activity as the extension of human capabilities through the creation of artifact, knowledge, and process. This view is very important because it implies that technology can be used to improve both system and individual performance; thus, it can be a tool for Human Resource Development (HRD) interventions.

Markert's (1993) definition of technology transfer is the most typical - she defined technology transfer as the development of a technology in one setting that is then transferred for use in another setting. However, this definition does not reflect a deep comprehension of technology transfer, because it is mostly focused on differentiating technology development from utilization. To overcome the disadvantage of this definition, Johnson, Gatz, and Hicks (1997) tried to interpret technology transfer through a holistic perspective that included both the movement of technology from the site of origin to the site of use and issues concerning the ultimate acceptance and use of the technology by the end user. They argued that recognizing the end user's needs and the context where the technology will be used is essential for the successful transfer of technology. Technology transfer is not the same process and perception for everybody. Universities, corporations, federal labs, and developing countries have different roles and interests in technology transfer. For example, universities, as a provider of technology, view technology transfer as a means for serving a community through knowledge sharing. On the other hand, technology transfer is regarded as a way to obtain competitive advantages through performance improvements in corporations that are the recipients of this technology. Like this, the perception of technology transfer in each site would be different. According to Frey (1987), technology can be an object, a process, or knowledge that is created by human intention. In most cases, technology tends to be the integration of all three components: object, process, and knowledge. Therefore, a provider of technology should try to transfer the integration of all components that make up that technology, not just one component.

Diffusion of Technology Innovations

According to Rogers (2003), diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system and by which alteration occurs in the structure and function of a social system as a kind of social change. Diffusion is an extremely critical process for the practical use of innovation and reinvention. In other words, diffusion plays a pivotal role in helping the adopters fully take advantage of an innovation and to modify that innovation. Thus, the comprehension of the major issues in the diffusion process is essential for making technology transfer successful.

Diffusion consists of four key elements: innovation, communication channels, time, and a social system (Mahajan & Peterson, 1985; Rogers, 2003). The issues of diffusion can be analyzed based on the main elements in the diffusion. According to Rogers (2003), innovations have five common characteristics that help to explain the rates of adoption; these can be relative advantage, compatibility, complexity, trialability, and observability. He argued that the greater relative advantage, compatibility, trialability, and observability and the less complex the perceptions of an innovation are, the faster the rate of adoption. Change agents need to use this implication to speed up the rate of diffusion and to make the potential adopters recognize the need for change.

In the diffusion process of innovations, the information exchange occurs through a variety of communication channels, such as mass media, interpersonal channels, or interactive communication (e.g., via the Internet). More effective communication occurs when two or more individuals are similar (i.e., homophilous). However, some degree of heterophily, the degree to which two or more individuals who interact are different in certain attributes, is usually present in communication about innovations (Rogers, 2003). It is important for change agents or HRD professionals to recognize these heterophilous aspects in order to enhance a mutual understanding for the innovation.

Diffusion occurs within a social system, and the social system constitutes a boundary within which an innovation is diffused (Mahajan & Peterson, 1985; Rogers, 2003). The social system has structure, giving stability and regularity to individual behavior in a system (e.g., as norms). The social structure of a system can facilitate or impede the diffusion of innovations in the system. For example, it might be very difficult for Catholic countries to adopt a new medical method for abortion. People whose religion is Catholic regard abortion as one of the biggest sins. Thus, the norm in Catholic countries would be reluctance to acknowledge abortion-on-demand. Consequently, the social structure of Catholic countries might impede the diffusion of a new medical method for abortion. In addition, the social system can influence the types of innovation decision: optional innovation decisions, collective innovation decisions, and authority innovation decisions; it can also influence the consequences of an innovation that are the changes that occur to an individual or to a social system as a result of the adoption or rejection of an innovation (e.g., desirable vs. undesirable, direct vs. indirect, and anticipated vs. unanticipated). This implies that change agents should understand the social system for planning the diffusion process effectively and efficiently.

Hall and Loucks (1978) developed the Concerns-Based Adoption Model (CBAM) based on the following assumptions about innovation adoption: (a) change is a process, not an event; (b) the individual is the primary target for change; (c) change is a highly personal experience; (d) individuals involved in change go through various stages; and (e) facilitators must know at what point their clients are in the change process. CBAM consists of seven stages: awareness, informational, personal, management, consequence, collaboration, and refocusing. These stages of concern about the innovation provide a key diagnostic tool for determining the content and delivery of individual development activities. Individuals with different kinds of concerns will be present in a group. For enhancing a diffusion process, individuals' concerns must be reduced. The most prevailing measure of stages of concern might be a 35-item stages of concern questionnaire (SoCQ) developed by Hall, George, and Rutherford (1977). Many researchers have often used it to measure the intensity of each stage of concern (Liu & Huang, 2005). Such use implies that the questionnaire is reliable and valid enough to provide both meaningful data and information for planning change strategies. Consequently, HRD professionals will be able to access guideline for change interventions by using CBAM.

Technological improvement tends to alternate between short episodes of intensive change activity and longer periods of routine use (Tyre & Orlikowski, 1993). Managing the timing of adoptions consciously and carefully can be a critical benefit for an organization pursuing both change and efficiency. Thus, managers need to devise plans for (a) creating opportunities for adoption, (b) utilizing those opportunities, and (c) exploiting periods of regular use of technologies for generating new insights and ideas. These plans will be helpful in tailoring new technologies to fit their organizational and strategic context.

Diffusion of innovations should be conducted in a two-way direction because it is a collaborative and context-specific process based on a mutual understanding about an innovation. Thus, adopters of technology should actively participate in customizing technology to fit their unique situation by considering both positive and negative aspects of technology. In addition, generators of technology should try to transfer resources and capabilities needed in order to use, modify, and generate technology to its adopters so that diffusion will be successful.

Technology Transfer, Organizations, and Culture

The three main aspects of technology practice are cultural, organizational, and technical (Pacey, 1986). Both the concept of maintenance and these three aspects of technology should be considered when making a technology transfer successful. However, most people tend to consider only the technical aspects, such as knowledge, skills, techniques, machines, and resources, in the technology transfer process. This lack of insight could be one of the biggest obstacles to making the technology transfer successful. Without a thorough analysis of both organizational and cultural issues related to technology, successful technology transfer cannot be expected.

Technological advances tend to increase complexity and uncertainty, make end users dependent on specialized experts, and build new knowledge hurdles for potential adopters. In cases of the diffusion of complex production technologies, knowledge and technical know-how become important barriers to diffusion. Most organizations delay in-house adoption of complex technology until they obtain sufficient technical know-how to both implement and operate it successfully. Reinvention and learning-by-doing might be responses to the difficulty or incompleteness of technical knowledge transfer between donor and recipient organizations (Attewell, 1992). Technical know-how is relatively immobile, and it must be recreated by user organizations. As a result, the burden of developing technical know-how through organizational learning becomes a hurdle to adopting new technology. Given such hurdles, the relationships between donor and recipient organizations in a network go beyond selling and buying equipment. Service is an alternative to adopting or not adopting a technology. In such a case, consumers obtain the benefits of a new technology by having someone else provide it as a service, rather than by taking on the formidable task of organizing the technology in-house for themselves (Attewell, 1992). In such scenarios, knowledge barriers are lowered and the process of technology diffusion is accelerated. Organizations that have already experienced the benefits of a technology via a service provider constitute a pool of already-primed potential adopters that are likely to adopt technologies in-house once knowledge issues or other barriers are removed (Attewell, 1992). Consequently, a transition will occur from service to self-service. In other words, shifts from market services to in-house deployment result from a progressive lowering of know-how barriers.

Lowering knowledge and technical know-how barriers could be achieved by the efforts of both donors and recipients of technology. Donor organizations must innovate, not just in their design of products, but especially in the development of novel organizational mechanisms for reducing the knowledge or learning burden upon recipient organizations. Recipient organizations should try to create and accumulate technical know-how regarding complex, uncertain, and changing technologies. This implies that HRD professionals should capitalize on a learning organization strategy as a framework for the successful transfer of technology. A learning organization focuses on the values of continuous learning, knowledge creation and sharing, systematic thinking, a culture of learning, flexibility and experimentation, and a people-centered view (Watkins & Marsick, 1993). This strategy is regarded as one of the most effective organizational strategies to use for adopting changing technologies. If the learning organization expands the concept of learning from the individual level to the team and organization level, this can help organizations effectively and efficiently create and accumulate technical know-how. Such a strategy for learning will contribute to enhancing the implementation of technology transfer as well as organizational performance by increasing learning and innovation. In addition, HRD professionals should try to create an environment that can induce the motives of both organizations and individuals to adopt new technologies for successful technology transfer. To do so, HRD professionals should strive to provide their potential users with opportunities to observe the benefits of new technologies.

Many post-World War II technical aid efforts by the United States and others failed because donor countries ignored and misunderstood both natural and cultural environments, assuming that all countries should follow the same pattern of industrialization (Pursell, 1993). The failure of these technical aid efforts led to appropriate technology movement; people realized that many useful technologies in donor countries might be detrimental in other countries and under other circumstances. Appropriate technology is primarily an innovation strategy aimed at achieving a good fit between technologies and the contexts in which they are intended to operate (Pursell, 1993). Values within the context play a pivotal role in determining the appropriate technology. In other words, appropriate technology aims at endogenous technological development within local communities and regions as a fresh approach to the problems of technology, society, and environment. Consequently, appropriate technology movement contributes to the importance of the contexts that involve cultural and natural environments in a technology transfer process.

People tend to maintain their own values and identities. This tendency led to the emergence of a variety of cultures. The beliefs, ideas, and customs that are shared and accepted by people in a society are based on cultural variables. Cultures often influence how technology is used in the technology transfer process. This fact is clearly supported by the case study for transfer of Western management concepts and practice from developed countries to Malawi. The aim of the case study was to relate findings to the education and training of managers in Malawi and consider their appropriateness (Jones, 1995). The finding recommended that Western management ideas must be critically examined in light of Malawian sociocultural realities (Jones, 1995). This implies that technologies must be tailored to fit the culture of end users in order for technology transfer to be successful.

Factors Affecting Technology Transfer

Technology transfer implies the movement of physical structure, knowledge, skills, organization, values, and capital from the site of generation to the receiving site (Mittelman & Pasha, 1997). The invisible aspects of technology, such as knowledge, skills, and organization, might be much more critical than the physical aspects for the successful transfer of technology. The case of the "Green Revolution" in India shows that technology is a form of knowledge created by humans, and knowledge transfer occurs as the outcome of a set of learning experiences (Parayil, 1992). This illustration implies that education and training play an important role in facilitating the movement of invisible aspects of technology. In other words, the capacity to assimilate, adapt, modify, and generate technology could be obtained through education and training.

The significance of education and training is also found in the cases of Japanese industrialization and Indonesian farm mechanization. In the early stage of Japanese industrialization, science and engineering universities and company schools contributed to facilitating the transfer of a marine steam turbine generator by providing capabilities for learning the new technology (Matsumoto, 1999). The capability of Japanese companies, acquired through education, made it possible to actively seek out new technology for the purpose of gaining competitive advantages, despite the economic risks.

On the contrary, Indonesian farmers failed to transfer agricultural machines for farm mechanization because of the lack of education, training, and other political and compatibility issues (Moon, 1998). Technology transfer should almost always involve modifications to suit new conditions. This implies that the unsuccessful transfer of agricultural machines in Indonesia resulted from the recipients' lack of absorptive capacity to assimilate and modify it rather than the donors' lack of sensitivity to local context for fitting the needs of end users. Technology is a passive resource whose effectiveness depends on humans. Consequently, one of the most critical components for effective technology transfer is a person's ability to learn new technology, which can be gained through extended education.

Although education is regarded as a critical and necessary factor for facilitating the transfer of technology, it is not sole factor for successful technology transfer. Another important factor could be effective planning for facilitating that transfer of technology. The plan should include concrete ways that recipients and donors can collaborate during the technology transfer process. Collaboration might be based on willingness for technology transfer from both the recipient and the donor. Without a strong willingness for technology transfer on both sides, it is impossible to assimilate, adopt, and generate new technology.

In the international technology transfer context, most technology transfers are primarily guided by the profit motive. A donor country seems reluctant to transfer knowledge or capacity to a recipient country without the hope for profit. The article entitled "Technology Transfer: A Third World Perspective" provides a great implication about the issue. Third World countries embarked on a massive but passive importation of technology (Akubue, 2002). Many recipient countries in the Third World adopted these innovations without modification. Akubue (2002) further notes that arrangements like this could be the result of a strategy of the donor countries aimed at making Third World countries continuously rely on them for maintaining the new technology. Through this strategy of technology transfer, the donor country might also gain an additional advantage over purchasing raw material, such as oil or gaining political influence in the recipient country, in addition to profiting from technology maintenance.

A critical test of technology transfers is whether they stimulate further innovations within the recipient country. Third World countries should be able to achieve technology transfer that stimulates further innovations through an elaborate plan. The plan should include the best ways to benefit both a recipient country and a donor country equally. This plan might prompt willingness of both the recipient and donor sides, which would result in strengthening collaboration for facilitating technology transfer.

A New Model of Technology Transfer

A country's competitive advantages increasingly lie in its capabilities to generate further innovations and to use effectively new technology, which is generally a function of the capacity of its population to absorb new technologies and incorporate them into the production process (Kolfer & Meshkati, 1987). This implies that a successful transfer of technology has a large impact on the advancement of a nation and it significantly depends on the capacity of people to assimilate, adapt, modify, and generate new technology. Consequently, educational infrastructure to develop "human capital" is the basic component for a successful technology transfer. After accumulating a high quality of human capital, a recipient of technology should develop an elaborate plan to increase the willingness of both the recipient and the donor of technology transfer. This plan could facilitate the transfer of technology by strengthening the collaboration between the donor and the recipient. Lastly, the recipient should be able to generate new innovations based on the successful transfer of technology. This model can be shaped as shown in Figure 1.

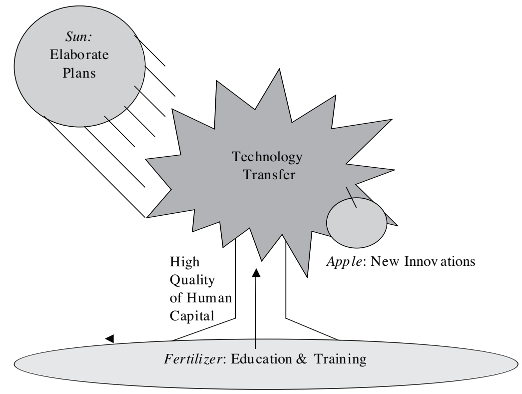

Figure 1. The role shifting model of technology transfer

This figure is titled "the role shifting model of technology transfer" because its ultimate goal is to generate new innovations. This model depicts how recipients of technology in 2009 can be tomorrow's donors of technology: It shows the conditions that enable fruit to ripen or in other words, new innovations. Thus, a high level of continuing education and training results in the role of fertilizing or helping an apple tree (technology transfer) grow well. In addition, elaborate plans for collaboration between recipients and donors help achieve successful technology transfer as either sun or rain is helpful for the growth of a tree. Consequently, farmers who are recipients of technology will be able to produce a plenty of fruit (new innovations) based on a high level of continuing education and training (fertilizer) and elaborate plans that play a role of sun and rain.

South Korea's successful transfer of technology for its national economic development might have followed the role-shifting model of technology transfer. South Korea transformed itself from an agrarian society to one of the world's most highly industrialized nations. The South Korean economy has grown remarkably through strong government support and engaged people (i.e., high quality of human capital) since the early 1960s. Koreans have tried to accumulate a high quality of human capital through education because Korea has few natural resources. Koreans regarded the export of its industries as the only means to get above poverty the early 1960s. As a result, government and business leaders together fashioned a strategy of targeting export-oriented industries for development in the early 1960s. The strategy involved plans for the successful transfer of technology that generates new innovations. This strategy was implemented in a series of economic development plans. Textiles and light manufacturing were the first targeted industries, followed in the 1970s by such heavy industries as iron and steel and chemicals. Later, the focus shifted to the automotive and electronics industries.

In the early stage of industrialization, Korea made concrete plans that included multiple steps for the transfer of technology due to strong government support. In addition, Korea possessed enough highly educated citizens to assimilate, adapt, modify, and generate this new technology. These factors made technology transfer in Korea successful, and they ultimately helped to achieve its remarkable economic growth. As a result, Korea became a donor of technology in high-tech fields, such as electronic, information technology, and communication.

Summary and Recommendations

For effective technology transfer, a provider of technology must first change the adopters' perception and willingness for the acceptance of technology by understanding their cultural and social values before transferring the information on technology. During this process, informal communication and relationships are very important (Johnson et al., 1997). Formal communication should precede informal communication in order to build credibility or obtain trust from the adopters of technology. The solid formal communication would be able to make the informal communication more effective.

The transfer of technology should be conducted as two-way communication, not one-way communication, because it is a collaborative and context-specific process based on a mutual understanding about an innovation. Providers of technology must play a key role in facilitating the transfer process by helping the adopter reconstruct technology, based on the given situation. Transferring technology helps the adopters reinvent innovation that is suitable for their environment. Thus, providers of technology should try to transfer to its adopters all resources and capabilities needed to use, modify, and generate the technology. In addition, adopters of technology should actively participate in customizing technology to fit their unique situation by considering both the positive and negative aspects of technology.

HRD professionals in donor organizations should create strategies to recognize the complex and distinctive realities of the contexts where technologies are intended to operate for the effective transfer of technology. One of the strategies might involve development of cross-cultural training. HRD professionals in donor organizations should conduct an elaborate and thorough context analysis in order to make cross-cultural training for technology transfer effective and efficient. In the process of context analysis, HRD professionals should thoroughly investigate the compatibility of technology, dimensions of cultural differences between donor and recipient organizations or countries, economical and political issues, and physical constraints affecting the use of technology.

In contrast, HRD professionals in recipient organizations should develop a transformational learning program for successful technology transfer. Transformational change at the organization level might be the result of double-loop or transformational learning that requires learners to change their mental schema in a fundamental way (Argyris, 1982). In other words, any organizational change cannot be made without a transformational change process. Therefore, transformational learning is vitally important for the successful transfer of technology in the recipient organizations. This implies that HRD professionals (i.e., change agents) should develop a transformational learning program to make a technology transfer process effective and efficient.

The successful transfer of technology can be achieved by generating new innovations. Technology transfer should not be seen as an end in itself. It is a means to increase the rate of technological innovation and to stimulate new innovation. Thus, today's recipients can be tomorrow's donors through a successful transfer of technology. To be a donor of technology, the recipients of technology should first possess the capacity to assimilate, adapt, and modify the imported technology through education and training. At the same time, the recipients should be more sensitive to technology cycles by continuously anticipating technology requirements as opposed to responding to them. This notion for recipients of technology to become anticipatory, not reactionary, is aligned with identifying emerging knowledge, skills, organizations, values, and trends. It can be a way to achieve the ultimate goal of technology transfer, which is actually developing new technology.

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"A Way of Revealing": Technology and Utopianism in Contemporary Culture

Alex Hall

Abstract

Although technology was once viewed literally as a means of bringing about utopian society, its means to that end was exhausted in the minds of many when it fostered the nuclear attacks on Japan in 1945. Since then, not only has technology lost its utopian verve, but it also has been viewed by some quite pessimistically. Nevertheless, technology does provide an avenue for utopian cultural production, whose utopian energy must often be rescued by readers and scholars using the Blochian utopian hermeneutic. In this way technology is as Heidegger described it—"a way of revealing," that is, the tool that brings the carving out from within the rock. This article argues that although technology has come to be viewed by some pessimistically in the years since Hiroshima and Nagasaki, it is now experiencing a utopian renaissance in that it allows for utopian cultural production to be widespread as never before. This is occurring thanks to new technology-facilitated genres such as the Alternate Reality Game, the mass audiences tuned in to Internet avenues for utopian production, and the continued improvement of older technologies such as film and television. Technology cannot be the impetus for ideal change by itself, no matter how embraced such a concept might have been upon the introduction of the telegraph or the Internet, but it has brought about new methods of injecting new energy into culture, which can only serve to benefit society as a whole.

"A Way of Revealing": Technology and Utopianism in Contemporary Culture

"Technology is a way of revealing. If we give heed to this, then another whole realm for the essence of technology will open itself up to us. It is the realm of revealing, i.e., of truth."

—Martin Heidegger

Despite the many views of technology associated with utopian thinking, one important role that technology plays is its facilitation of idealistic cultural production—literature, music, visual arts, media. This role can be as simple as the tools that allowed prehistoric man to create cave paintings, or as advanced as contemporary cultural production platforms (e.g., the Internet and film technologies). If the hermeneutic employed by subscribers to the philosophy of Ernst Bloch is accepted, then utopian potential can be found in any cultural product. Since most cultural production is dependent upon technology in one way or another, then it hardly seems a stretch to grant technology some credit in the area of utopian potential, despite what it leaves to be desired in others. Still, the history of technology's relationship with utopianism is quite complicated, especially with regard to technology as a means to a socially utopian end.

Enlightenment thinkers saw technology as one of several means of bringing about a perfect world, but they also recognized its inherent negative possibilities. Technological utopian visions flourished; however, technology remained an object of considerable debate, especially in the wake of the nuclear attacks on Hiroshima and Nagasaki, Japan in 1945, and throughout the Cold War. At this point, technology all but entirely ceased to be the means to utopia it had once been credited as, and in fact became quite the opposite in the minds of many, among them Herbert Marcuse. Nevertheless, technology resulted in significant gains in the areas of cultural production, which allowed for utopian visions to be explored, even if an application of an interpretation of a perfect world was necessary for them to be recognized. Today, technology remains that which allows for cultural production to communicate messages of hope, which exemplifies Martin Heidegger's (1977) idea of technology as "a way of revealing" (p. 12), but technology cannot be the locus for utopian change by itself. In spite of this, new technological innovations might be evidence of a kind of technological utopian renaissance within cultural studies, as new technology-facilitated genres (e.g., Alternate Reality Games, mass audiences tuned into Internet avenues for utopian production), and the continued improvement of older technologies, (e.g., film and television) build on technology's arsenal of cultural production outlets.

Technology and Utopianism: A Brief History

A look at attitudes toward technology and utopianism from Thomas More to the Enlightenment (and, indeed, beyond) shows the complicated correlation between the two in history. M. Keith Booker (1994) credited More with including in *Utopia* " 'natural science' among the pursuits that bring moral and cultural improvement to the citizens of his ideal society," and noted that "science has been linked to utopian thinking since the very beginnings of modern science in the seventeenth century" (p. 5). If science and technology are "interdependent," as Walter L. Fogg (1975, p. 61) pointed out, then Booker's observation holds true for the relationship between technology and utopianism as well.

Though More's *Utopia* appeared in the sixteenth century, it defined a literary genre, of which Francis Bacon's *New Atlantis* is a part. Booker (1994) called *New Atlantis* "one of the most optimistic imaginative projections of the beneficial impacts that science and technology might have on human society" (p. 5), whereas Fogg (1975) considered Bacon a "thinker who saw the potentialities of modern science" and "the growth of scientific knowledge as an historical moment, a collective, incremental enterprise, a revolution in which man would control nature, reform his fundamental conception of things, and bring about peace and plenty on earth," calling him "the prime example of a utopian who firmly believed that the practical application of the new science and technology meant the progress of mankind" (pp. 61-62). It is worth noting that Nell Eurich (1967), in her *Science in Utopia*, saw Robert Burton's "pragmatic approach to a better state" as presented in the "Preface of Democritus Junior" in The *Anatomy of Melancholy* as that which "prepared the stage for the entrance of the new scientific utopia" (pp. 91-92)—even if Burton (1948) saw utopia as something "to be wished for, rather than effected," and the literary scientific utopia *New Atlantis*, among other literary utopias[1], as "witty fictions, but mere chimeras" (p. 101). Still, according to William Rawley's (1982) introduction to *New Atlantis*, "most things therein are within men's power to effect" (p. 418).

Howard P. Segal (2005) agreed that these works position technology as a means to a utopian end, but pointed out that "their authors remain sufficiently wary of mankind to propose establishing limits within utopia," and so "envision a fixed, unchanging society without further technological progress" (p. 59), which is consistent with Booker's (1994) observation that "even during the triumphant rise of science to cultural hegemony in the seventeenth and early eighteenth centuries, writers . . . were already warning of the potential dangers (especially spiritual) of an overreliance on scientific and technological methods of thought and problem solving" (p. 6). Even so, Segal (2005) pointed to the Marquis de Condorcet's anticipation of "scientific and technological advances surpassing those imagined by Bacon" (p. 59) as evidence of the evolution of technology's relationship with utopianism.

Condorcet, near the end of the eighteenth century, and according to Segal (2005), "evinces an unprecedented optimism about the prospects for realizing utopia: its realization, [Condorcet] believes, is virtually at hand . . . and he grants technology an unprecedented role in establishing utopia" (p. 60). However, Condorcet's hope for humanity's ability to reach utopia is not entirely based in the evolution of technology. Segal (2005) pointed out that "increasing secularization, education, and equality" were the variables to which Condorcet credited "mankind's advances," and that "the technological advances he so carefully and lovingly [delineated] are only indications of the way society is moving generally, not blueprints for a specific future society" (p. 60).

> Following Condorcet, Henri de Saint-Simon and his student Auguste Comte recognized the importance of technology in utopian thought. Saint-Simon, according to Segal (2005), argues that the intellectual, social, and cultural unity that Europe once enjoyed has collapsed under assault by Protestantism, Deism, empiricism, nationalism, and commercialism. A new unity must be forged, and its basis must be ideological. The ideology that is to forge this unity is science, which will replace the divisive and shaky world views currently presented by religion. Science is to be applied in the practical form of "industry," which includes both manufacture and distribution and which amounts to technology. (p. 61)

Although he eventually abandoned his absolute technological position, he agreed with Comte, whom he also separated himself from intellectually near this time, on what Segal (2005) termed "the need for science and technology to solve major social as well as technical problems" (p. 61).

Following the intellectual trend of viewing technology as an integral part of utopian realization, Karl Marx and Friedrich Engels too saw the potential of technology for social liberation. According to Segal (2005), "[Marx and Engels] repeatedly hinted at a society radically superior to the existing capitalist one, which would utilize modern, especially automated, technology as a principal means of freeing the proletariat. The proletariat would be liberated not simply from their long-standing alienated labor but also for other, more varied and fulfilling activities" (pp. 69-70). Despite this view, Jacques Ellul (1967) later questioned why technology failed to achieve this liberation and, instead, threatened to overwhelm society (p. 44). This viewpoint seems to question why technology had achieved quite the opposite of what Marx hinted at, and in effect engulfed any hope of his vision coming to fruition. This is because "[Marx] preached that technique can be liberating," and so "the masses went over to the side of technique; society was liberated," but "those who exploited [technique] enslaved the workers" (Ellul, 1967, p. 54-55). It was the exploiters that thwarted Marx's vision through said domination, leaving the workers only with consumer capitalism, rather than a "superior" society fueled by technological advance. According to Booker (2002), "such changes necessarily left a certain emptiness in the American soul, an emptiness that the flood of commodities produced by this new consumer capitalist system was not likely to be able to fill," and "the system was, in short, fundamentally anti-utopian, and even more so than nineteenth-century industrial capitalism, which drew upon the legacy of the Enlightenment to produce at least the notion that a stable happiness could be achieved" (p. 22). A large part of technological utopian potential that remained under consumer capitalism existed in cultural production.

Having been instituted as that which oppressed rather than liberated, technology lost whatever tangible value it once had as a means toward the perfect world. Many people's attitudes toward technology became increasingly pessimistic, as did attitudes toward the possibility of ever reaching utopia, which was a key achievement of the consumer capitalist system. But one positive aspect of technology remained: its facilitation of cultural production, which was bolstered, in fact, by consumer capitalism. According to Booker (2002), the consumerist revolution of the first three decades of the twentieth century did help to create new and different kinds of culture. In particular, the new consumerist ethos, combined with certain technological advances (such as the development of commercially viable film technologies), helped to trigger an explosive growth in the production and distribution of popular culture . . . The film industry was born. Increases in print technology made it feasible to produce large numbers of books to be sold at low prices; rapidly rising literacy rates ensured that the masses, now able to afford books, could also read them. (p. 23)

Booker (2002) also stated that "the strongest utopian energies in American Culture of this period were to be found not in high culture but in popular culture," citing the work of authors such as Edgar Rice Burroughs as having offered "fantasy escapes from the humdrum routine of everyday capitalism, assuring Americans that it was still possible to experience some sense of adventure while living in the workaday world" (p. 23). What is clear from all this is that technology is that which made it possible to inject utopian energy into culture. Since culture is where much utopian potential is located, and technology is that which facilitates culture, then it is fair to say that Heidegger's (1977) assertion about technology as "a way of revealing" (p. 12) holds true, which is to say that technology is a way of revealing utopian longing/potential in/through culture.

Heidegger and Technology as "A Way of Revealing"

Heidegger's discussion in "The Question Concerning Technology" fundamentally deconstructed the very idea of technology, and did so in a way that serves thinking about it as that which reveals utopian energy in culture. One of the first points that Heidegger (1977) made about technology is that it is at the same time "a means to an end" and "a human activity"—this is what he termed the "instrumental and anthropological definition of technology" (pp. 4-5). It may be useful at this point to think of culture as both a human activity and an end, while positioning technology as the means, but the instrumentality involved in making this so, according to Heidegger (1977), makes it a cause, because "the end in keeping with which the kind of means to be used is determined is also considered a cause" (p. 6). To illustrate this point, Heidegger (1977) used a silver chalice as an analogy, and placed it within the philosophic model of causality—the silver used to craft the chalice is the causa materialis, the form of the chalice that the silver takes is the causa formalis, the purpose of the chalice is the causa finalis, and the silversmith that brings the chalice out from within the silver ore is the causa efficiens (p. 6). Heidegger (1977) continued by offering that "what technology is, when represented as a means, discloses itself when we trace instrumentality back to fourfold causality" (p. 6), but he did not yet reveal what was meant by that "what." Still, it is useful at this point to look at (utopian) cultural production through the scope of this "fourfold causality."

Within the philosophical model of causality, it can be inferred that the causa materialis of utopian cultural production is the cultural technique itself, its utopian dimension or form the causa formalis, its message of hope or resistance to the oppressive nature of consumer capitalism the causa finalis, and the person responsible for the product—an author or filmmaker, for instance—the causa efficiens. The raw material of the utopian cultural product is the cultural technique used to produce it, which, according to Heidegger's (1977) logic, makes it "co-responsible" for the product along with its "aspect" (p. 7) of utopianness—that is, it does not take an anti-utopian or other contradictory form. These two causae combine to equal not the purpose of the utopian cultural product, but rather, by Heidegger's (1977) logic, the result of it—resistance to the current system and anticipation of a better one. The author "gathers together" these "ways of being responsible and indebted" (p. 8) to "bring" the utopian cultural product "into appearance" (p. 9). This "bringing-forth" (p. 11) as Heidegger (1977) eventually termed it, is equivalent to "revealing" (p. 11), leaving him with the question "what has the essence of technology to do with revealing?" to which he answered "everything" (p. 12). Revealing, then, is the "what" that Heidegger leaves unexplained earlier in his discussion. This revealing is important to a utopian hermeneutic.

Technology's Role in a Utopian Hermeneutic

A utopian hermeneutic allows for the locating of utopian potential in any cultural product. As articulated by Fredric Jameson (1976), utopian hermeneutics "offer an analytical tool for detecting the presence of some Utopian content even within the most degraded and degrading type of commercial product" (p. 58). It is technology that reveals this utopian content in cultural production—as if making it tangible from the ether (upper air or sky)—but it is the theory of idealism that allows critics and scholars to tease it out. Utopian energy is manifested in several ways, however, and given the dystopian nature of life under consumer and late capitalism, what is often recognized by critics and scholars as utopian energy in the cultural products produced under these systems is a utopian longing. Jameson's ideas regarding utopia and cultural production were informed by Ernst Bloch, who, according to Jameson (1976) "sees [the Utopian principle's] in-forming presence at work everywhere, in all the objects of culture as well as in all social activities and individual values or more properly psychological phenomena" (p. 56). According to Heidegger (1977), the "bringing-forth" (p. 12) that is involved with technology is also involved with "the arts of the mind and the fine arts," and it is in this "realm" that "revealing and unconcealment take place" (p. 13). In this sense, it is through technology that a revealing of utopian potential can take place—technology facilitates the cultural product to begin with, and the utopian hermeneutic (i.e. the method or theory of idealism) uncovers its utopian potential.

Heidegger's interpretation of what technology is, however, did not discount the negative implications of technology. According to Booker (2002), "the atomic bombing of Hiroshima and Nagasaki was not an entirely new departure as much as it was a final straw that that finally broke the back of the American national narrative, leading it to collapse beneath its own weight" (p. 12). This turn of events also served to bring about a perceived pessimism toward technology. Leo Marx (1994) explained that "in the aftermath of World War II . . . what had been a dissident minority's disenchantment with this overreaching hero [technology] spread to large segments of the population" (p. 22). The way in which Heidegger's deconstruction of technology treated cultural production has its root in the Greek *poi_sis*, which Heidegger (1977) defined as "a bringing-forth" or "artistic and poetical bringing into appearance and concrete imagery" (p. 10), but his view of what he called "modern technology" is quite different, and this is where that he touched upon the negative implications of technology. He wrote that "the revealing that holds sway throughout modern technology does not unfold into a bringing-forth in the sense of *poi_sis*. The revealing that rules in modern technology is a challenging, which puts to nature the unreasonable demand that it supply energy that can be extracted and stored as such" (p. 14). The example Heidegger (1977) gives is a challenging of nature: "Air is now set upon to yield nitrogen, the earth to yield ore, ore to yield uranium, for example; uranium is set upon to yield atomic energy, which can be released either for destruction or for peaceful use" (p. 15). Although Heidegger does leave room for the peaceful possibility of harnessing atomic energy, Langdon Winner (2004) pointed out that "following accidents at Three Mile Island and Chernobyl as well as the economic meltdown of the U.S. Nuclear power industry, the atomic dreams of the 1950s were heard as mere clicks on the Geiger counters of historical background radiation" (p. 36). This negative result of the implementation of atomic energy superseded whatever peaceful implications there had been for it, which, coupled with Heidegger's delineation of technology's ability to transform nature into both capital and destructive power, fostered the onset of the technological pessimism that followed the second World War.

Technology and Pessimism

Technological pessimism might well be considered a dystopian view of technology. In fact, this is precisely how Bernard Gendron (1977) referred to it when he characterized it as "the exact opposite of the Utopian view," which, he explained, holds that "all or most of our social progress is due primarily or exclusively to the growth of technology" (p. 3). Subscribers to the so-called dystopian view, however, "believe that technological growth in the long run generates or intensifies many more social evils than it reduces or eliminates" (Gendron, 1977, p. 3). To anticipate the inevitable criticism of this binary division between the utopian and dystopian views, it might be more useful to think of what Gendron calls the dystopian view as the anti-utopian view of technology. One example of an anti-utopian view might be that of Herbert Marcuse (1964), who granted that on the exterior "the 'end' of technological rationality" seems to be "a goal within the capabilities of advanced industrial society," but ultimately found that

> the contrary trend operates: the apparatus imposes its economic and political requirements for defense and expansion on labor time and free time, on the material and intellectual culture. By virtue of the way it has organized its technological base, contemporary industrial society tends to be totalitarian. For "totalitarian" is not only a terroristic political coordination of society, but also a non-terroristic economic-technical coordination which operates through the manipulation of needs by vested interests. (p. 3)

Marcuse's view of technology as a controlling force is a concrete example of an anti-utopian (and therefore a pessimistic) view of technology. Early examples of pessimism toward technology e.g., Heidegger's (1977) and Marcuse's technologically pessimistic attitude put forth in 1964 are evidence of the onset of technological pessimism in critical theory. A culmination of this mode of thought toward technology can be found in the Spring 1980 issue of *Alternative Futures*—a special issue appropriately entitled "Technology and Pessimism." The preface to that issue regarded technological pessimism as "a fundamental problem in much thinking about the future and indeed . . . a major intellectual current in the past century and a half: fear of technology" (Barton & Stevenson, 1980, p. 3). The essays in this issue varied according to critical perspective, but often were interested in stripping pessimism away from technology[2] in order to move beyond pessimistic attitudes and embrace a future made *better* through technology. (Segal [1980] himself saw this perspective as evidence of "considerable faith in technology's ability to solve problems and to improve society" [p. 139].) Other essays in the collection, however, exemplified the continuing pessimistic attitude toward technology that is characterized by pessimism.[3] This binary divide between the views of technology, however, still does not account for the ability of technology to provide an avenue for utopian cultural production. Nonetheless, one author whose work appeared on the more utopian side of the debate was Leo Marx (1980), who considered the prophetic nature of technology and pessimism in American literary culture, and saw the tendency of some people to maintain a pessimistic view as those who "are better able to identify with residual than emergent elements of the culture" (p. 69). Despite these utopian leanings in the face of the rise of technological pessimism in the twentieth century, both Segal and Marx would go on to identify a continuing thread of the anti-utopian view of technology within postmodernism.

Under postmodernism, this anti-utopian view of technology has continued. According to Segal's (1994) introduction to the Sociology of the Sciences 1993 Yearbook, *Technology, Pessimism, and Postmodernism*, "technological pessimism has become an integral part of the emerging culture of postmodernism. Within that cultural hierarchy, technology itself may be assuming a declining status amid a growing disenchantment with material success and with all forms of social and political engineering" (p. 3). Marx's (1994) contribution to this volume suggested that the pessimism associated with postmodernism is a "vision of a postmodern society dominated by immense, overlapping, quasi-autonomous technological systems" (p. 25). Following Jameson's (1991) conception of postmodernism "as an attempt to think the present historically in an age that has forgotten how to think historically in the first place" (p. ix), then, Segal (1994) noted that "high tech is lacking in the very historical consciousness that would in turn temper its optimism and thereby, most ironically of all, perhaps strengthen its appeal" (p. 211). At this point the binary opposition of the utopian and anti-utopian views of technology converge between the two poles of anti-utopia and utopia to become a truly dystopian mode of thought regarding technology that is akin to Tom Moylan's (2000) discussion of dystopian narrative as that which "enters the fray between Utopia and Anti-Utopia" (p. 139). This can be understood via the description by editors Marita Sturken and Douglas Thomas (2004) of the essays in *Technological Visions: The Hopes and Fears that Shape New Technologies* as making clear "that society's capacity to project concerns and desires on technology operates as a primary form of social denial; the belief that a new technology can solve existing social problems reveals a refusal to confront fully the deeper causes of those problems" (p. 3, emphasis added). Such a dystopian attitude toward technology in critical theory leaves space for a seemingly as yet unexplored consideration of technology's facilitation of utopian cultural production.

The dystopian nature of the technology debate—that perspectives tend to fall between the utopian and anti-utopian—necessitates a conception of culture as a production of technology (insofar as technology facilitates the production of culture, not that technology possesses the agency of cultural production in general). Technology allows for the production of culture, and utopian potential can always be found in culture—here lies a notion of technology that leans toward the utopian pole of the dystopian mode of thought surrounding technology in critical theory. In fact, Walter Benjamin's (2001) ideas about the role of technology in the production of culture hinted at this notion when he wrote that "around 1900 technical reproduction had reached a standard that . . . permitted it to reproduce all transmitted works of art and thus to cause the most profound change in their impact upon the public" (p. 1168). This impact seems to be the change from a mere enjoyment of a cultural product to critical analysis of it, which, again, is precisely the energy that is needed to employ a utopian interpretation to the product, and thereby tease out its utopian potential. Though Benjamin principally discussed how this is so for film, it is certainly true for the technological facilitation of culture in general, now that new media has entered the debate. An example of how new media politicizes the reception of cultural products is shown next in the Alternate Reality Game (ARG) that is offered for analysis.

The Utopian Potential of Technology Exemplified: The Alternate Reality Game

The Alternate Reality Game (sometimes referred to as ubiquitous or immersive gaming) is an example of an immersive cultural product that can be broadcast across multiple types of media. Players of ARGs might make or receive phone calls, send or receive packages via the United States Postal Service, find hidden messages (in films, television shows, websites, musical recordings, and more), and receive e-mails—all pertaining to the game. Through these avenues, a fragmented narrative turns up that gamers then set out to collectively piece together or solve by participating in the game on message boards. A utopian dimension of the very existence of such a medium is inherent in the fact that, as notable game scholar Jane McGonigal (2003) points out, "immersive gaming is actually one of the first applications poised to harness the increasingly widespread penetration and convergence of network technologies for social and political action." This logic, however, engages in the either-or fallacy of the technological debate that the present analysis is attempting to undermine. Better to espouse the cultural impact of games in general (including ARGs) as outlined by Katie Salen and Eric Zimmerman (2003) in their keynote address from the 2003 Digital Games Research Conference; as they put it, blurring the boundaries of a game's "magic circle" (pp. 14-15)—the frame or context—and designing a game "as a cultural environment is an effective way to mount a powerful cultural critique" (p. 28). Technology remains the platform for the design of the game, which contains utopian potential in its cultural critique, and it is in this way that technology reveals utopian potential in the ARG. An exemplary ARG viewed through the scope of this analysis is *Year Zero*, an ARG that mounts its cultural critique via the generic conventions of the critical dystopia.

Year Zero's ARG is an extension of a narrative vision of history conceived by Trent Reznor—a musician whose "industrial" rock band *Nine Inch Nails* is his creative outlet, and for which he produces all of the material. The narrative influenced the production of this band's album of the same title (released in 2007), but it became much more in the ARG. A concert tour T-shirt sold at *Nine Inch Nails* performances in Europe before the official release of the album component of *Year Zero* had certain letters highlighted in the tour schedule to spell out the words "I am trying to believe," which fans soon discovered was actually a website address. The website showed *Year Zero's* narrative to be set in the near future_2022, or "year zero"_during which time Americans are being exposed to a drug supposed to strengthen the immune system against biological attacks. One such attack is said to have taken place, but the author of *I Am Trying to Believe* assumes it was a staged attack that allowed the conservative Christian, totalitarian government in power to put the drug, "Parepin," into the water. There are some side effects to the drug, which people who stop drinking the water notice they no longer have_these include an inability to think clearly and a loss of sex drive. Readers are encouraged to contact the site's author via an e-mail address provided on the web page (http://www.iamtryingtobelieve.com), but the reply suggests that the author has been compromised, as it dispels the original warnings in a way that is consistent with the ideology of the government in power, even suggesting that the author has been re-subjugated, allowing the government to perpetrate the "auto response" (water@iamtryingto-believe.com, personal communication, September 28, 2007) itself. Using song titles from the album, gamers found upwards of thirty additional websites, marking a complexity of the ARG that they eventually set up a wiki to keep track of in addition to Internet message boards. Many of these additional websites were revealed through technological means such as a color change finish to the *Year Zero* compact disc and spectrographs of songs leaked on USB flash drives planted at concerts. Other components of the ARG were discovered by calling a number on the back of the digipak the album was packaged in, and by meeting with actors portraying characters in the game. Some gamers were even given cellular phones and sent text messages directing them to locations where still other clues were revealed. Many aspects of the game's alternative reality are linked to aspects of the gamer's empirical world (one example is an explicit charge that the USA PATRIOT Act could lead to much of what is wrong with the future world of the game in reality), which encourages the kind of historical thinking associated with the conventions of the critical dystopia. Lyman Tower Sargent (2001) defines the critical dystopia as "a non-existent society described in considerable detail and normally located in time and space that the author intended a contemporaneous reader to view as worse than contemporary society but that normally includes at least one eutopian enclave or holds that the dystopia can be overcome and replaced with a eutopia" (p. 222). In *Year Zero*, historical thinking comes into play in that the present exists as the "eutopian enclave" that can overcome the narrative's imagined future through prevention. This manifestation of historical authenticity in *Year Zero* is consistent with the inherent emergence of the utopian imagination in the critical dystopia explained as follows by Tom Moylan:

> as the critical utopias of the 1960s and 1970s revived and transformed utopian writing (by negating the anti-utopian tendency through a dialectical combination of dystopia and eutopia to produce texts that looked not only at what was and what was to be done but also at how the textual work self reflexively articulated that political imaginary), the critical dystopias of the 1980s and 1990s carry out a similar intertextual intervention as they negate the negation of the critical utopian moment and thus make room for another manifestation of the utopian imagination within the dystopias form. (pp. 194-195)

As a critical dystopia, *Year Zero* brings about the utopian imagination on the part of t he gamer. As a cultural product housed within new media, it uses technology to put forth its narrative. Because there is utopian potential within *Year Zero*, and because it is facilitated by technology, it demonstrates how technology facilitates utopian cultural production, and thus it undermines the binary opposition between the two poles of the technology debate in critical theory, tending instead to find utopian potential in technology within a more cultural theory.

Conclusion

Scholars and philosophers have long recognized that technology played an important role in utopian thinking during the Enlightenment as a means to the realization of utopia. This is evident in the scientific utopias and in the works of utopian thinkers that appeared during this time. What is also evident, however, is that there was a perceived understanding of the inherent dangers of technology. This last became paradigmatic as time passed, especially with the rise of consumer capitalism. Nevertheless, consumer capitalism did usher in new means of cultural production, much of which were facilitated by technology. Because utopian potential can always be located in cultural production through the application of a utopian method or theory of interpretation á la Bloch, technology itself was able to retain at least one utopian quality through this facilitation. Heidegger's (1977) concept of technology as "a way of revealing" (p. 12) supports this claim to the extent that technology reveals utopian energy in culture because it acts as an outlet for culture. Still, Heidegger recognized the dangers of technology, which is exemplary of the strengthening of the technological pessimism paradigm after World War II. Yet, a strong critical framework opposed this pessimistic attitude in years to come, marking a polarization between utopian and anti-utopian views of technology and leading to a dystopian view of technology in general. But the dystopian view of technology is too narrow in its focus on what technology will or will not do. As Langdon Winner (2004) suggested, "perhaps it is time to affirm that we have heard the false promises and hyperbolic speculations too often, that it is time for this strange alchemy to cease" (p. 46). By accepting technology as a tool for cultural production, the emphasis can be placed not on the technology itself, but on the utopian potential of the cultural production it facilitates.4 In this way, a critically dystopian ARG such as *Year Zero* can perhaps be viewed as what Heidegger (1977) called a "poetic revealing" (p. 35), thereby allowing technology to "expressly foster the growth of the saving power" of culture, and "awaken and found anew" (p. 35) our conception of the power of technology.

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Notes

1. Andreae's Christianopolis and Campanella's City of the Sun, for instance.

2. The essays by Melvin Kranzberg and Samuel C. Florman are examples.

3. John H. Broomfield's "Technology and the Tragic View" for instance.

4. Consider the recent trend of some artists in the music industry to give their work away for free on the Internet—Nine Inch Nails among them. This allows the artists to avoid the filter of record executives interested solely in the proverbial bottom line. The visual arts have also long embraced the Internet as such a forum. Additionally, novelists and graphic novelists have used this platform for their works. Once again, technology facilitates the cultural product, which can be found to contain utopian potential.

Technology Teachers' Beliefs About Biotechnology and Its Instruction in South Korea

Hyuksoo Kwon and Mido Chang

Abstract

The increased public awareness of the significance and necessity of biotechnology has encouraged educators to implement biotechnology instruction in various educational settings. One example is the great effort made by educational researchers and practitioners internationally to integrate biotechnology in technology education. Despite the gains in the popularity of biotechnology in education, the actual implementation of biotechnology instruction is not prevalent. Previous studies suggest that technology teachers' beliefs are a significant predictor of the implementation of biotechnology instruction for technology education. Thus, there is a need for further studies on this topic, however, this study investigates Korean technology teachers' beliefs related to the implementation of biotechnology instruction. It also includes several issues that are implied by the findings. A piloted self-reported online survey developed by the authors was administered to 114 Korean middle school technology teachers. This survey collected demographic information and measured these teachers' intent to implement biotechnology instruction into their classes (*intent*). The teachers' beliefs were measured in three domains: *value* (technology teachers' perceived beliefs about biotechnology teaching as valuable); *expectancy* (technology teachers' perceived beliefs about biotechnology teaching as expectancy); and *innovation* (technology teachers' perceived beliefs about biotechnology teaching as a need regarding innovation). Results indicate that Korean technology teachers' beliefs measured by value, expectancy, and innovation were significantly associated with teacher intent to teach biotechnology content in their classes. This study recommends that biotechnology content should be delivered systematically to technology teachers through professional development (i.e., in-service and pre-service training).

Introduction

Due to the pervasive impact of biotechnology, leaders in education have begun to focus on using educational settings to increase public awareness related to the benefits and impact of biotechnology (International Technology Education Association [ITEA], 2000). Within the educational community, researchers, authors, and practitioners in specific fields of education, such as technology education (ITEA, 2000), science education (Glenda & Schibeci, 2003; Steele & Aubusson, 2004), and agricultural education (Wilson, Kirby, & Flower, 2000) have realized the importance of implementing biotechnology instruction at secondary level. Technology educators have gone a step further by focusing on biotechnology as a major content organizer for technology education programs and advocating adding it to technology education programs (ITEA, 1996; ITEA, 2000; Savage & Sterry, 1991; Wells, 1994).

Despite the position taken by the technology educators, biotechnology has not been broadly implemented in technology education programs (Brown, Kemp, & Hall, 1998; Rogers, 1996; Russell, 2003; Sanders, 2001). Technology teachers' beliefs about biotechnology and its instruction have been found to be a factor in the implementation of biotechnology teaching (Daugherty, 2005; Scott, Washer, & Wright, 2006). These researchers focused on diagnosing the current conditions of biotechnology instruction in technology education and suggested that further systematic studies be undertaken to investigate technology teachers' beliefs as related to the low implementation.

There have been significant efforts to incorporate technology education into general education worldwide. Technology education was introduced in the second revision of the national curriculum in South Korea in1969. The technological revolution, especially the biotechnology revolution, resulted in the addition of significant biotechnology content in the recent South Korean national curriculum revisions (Yi, Lee, Chang, & Kwon, 2006). However, actual implementation of biotechnology instruction within the technology education curriculum has been limited (Korea Institute of Curriculum and Evaluation [KICE], 2002), compared to other content areas (e. g., manufacturing, construction, and transportation). Wells and Kwon (2008) pointed out that Korean technology teachers' low implementation of biotechnology instruction resulted from both a lack of motivation and insufficient training.

Teachers' beliefs affect their decisions regarding the content they teach and the ways in which they teach that content. In particular, technology teachers' perceived beliefs about biotechnology teaching as valuable and their perceived beliefs about biotechnology teaching as expectancy, affected the teachers' willingness to implement a curriculum in their classrooms (Abrami, Poulsen, & Chamber, 2004; Kay, 2006). In this context, Korean technology teachers' beliefs about biotechnology and its instruction can affect the implementation of this subject and the form it will take.

Background to the Study

Biotechnology in Korean Technology Education

The educational system in South Korea follows a single track (ladder type), consisting of elementary school (six years), middle school (three years), high school (three years), and junior college, college and university undergraduate study (two or three, four or six years), and it is based on a strong national curriculum. Since 1948, the national curriculum has undergone seven revisions as educators have adapted to new educational needs and technological changes. As early as 1970, extensive knowledge of technology was recognized as important for all citizens, regardless of age or gender. Since then technology education has been taught as a separate subject and integral part of general education under the name of "*kisul*" (literally, "technology"). Throughout the past three decades, there have been innovations and challenges in curriculum, instruction, and teacher education in Korean technology education and Korean technology educators have faced new challenges and expectations whenever the curriculum has been revised (Yi & Kwon, 2008). Initially in 1970, Korean secondary schools started to offer technology programs that included educational goals such as career guidance and vocation, consumerism, and the study of industry and technology. Today, the technology curriculum for secondary schools follows differing content at different grade levels. In 7th – 10th grades students learn *Technology- Home Economics*, and in grades 11 and 12, students select from among *Information Society and Computers, Agricultural Science, Industrial Technology, Enterprise Management, Ocean Science, and Home Science.*

Another challenge in Korean technology education has been the lack of qualified technology teachers (Yi & Kwon, 2008). In Korea, secondary school teachers are graduates of a four-year teachers' colleges. However, in the early days of technology education, there were no qualified technology teachers in secondary schools because there were no teachers' colleges for the subject of technology. Chungnam National University graduated its first class of technology teachers in 1985, and Korea National University of Education graduated its first class of qualified technology teachers in 1995 (Kim & Land, 1994). Recently, Daebul University has graduated qualified technology teachers. The shortage of qualified technology teachers is thus being addressed resolved through the efforts of these three university programs. However, there is still a lack of talented technology teachers who have the ability to overcome systematic problems (e. g., the lack of necessary weekly class hours and the lack of needed laboratory facilities) and being capable of engaging in innovative technology teaching and learning. Considering the significance of biotechnology as a content organizer within Korean technology education, the design and development of biotechnology courses for pre-service technology education teachers should be made a priority. However, a review of the curriculum used by these institutes indicates that courses related to biotechnology are still insufficient.

Biotechnology content in the national curriculum initially stemmed from agricultural content in the elementary school (boys and girls) and middle school (girls). Because of the needs of society in the 1970s, the agricultural content had a significant place in technology education. By the sixth curriculum revision, biotechnology had become established in secondary school technology courses (KICE, 2002; Yi & Kwon, 2008). However, Korean technology educators are currently preparing for a new curriculum in a partial revision of the seventh national curriculum. The new curriculum is being developed to correct perceived weaknesses and to meet the needs of students, teachers, and society. Based on curriculum research, the new Korean technology education curriculum has been constructed using five curriculum content organizers: manufacturing, construction, communication, transportation, and biotechnology. The new technology curriculum incorporates learning content based on technological systems and students' hands-on activities. Table 1 depicts the two main features of the structure of learning contents for Grades 7 to grade 10. A basic structure of learning content and sub-content is compulsory while there is also a minimum level of knowledge and hands-on activity specified. In particular, "technology and invention," "Korean traditional technology", and "biotechnology" are new categories of learning content, introduced for the first time in the new technology curriculum.

Table 1. Learning Contents of New National Technology Curriculum in Secondary School

Grade	7th Grade	8th Grade	9th Grade	10th grade
Learning Contents	Technological Development and Future Society	Information and Communication Technology	Electronics and Machine Technology	Vocation and Career Design
	Technology and Invention	Manufacturing Technology	Construction Technology	Transportation Technology
			Biotechnology	

As awareness of the importance of teaching biotechnology increases, Korean technology education has adopted and developed biotechnology instruction. Even though the Korean educational system follows a strong national curriculum, the implementation of teaching biotechnology is dependent on each technology teacher. In other words, technology teachers' beliefs about biotechnology and its instruction affect both their decisions to implement biotechnology instruction and their performance once it is introduced.

Technology Teachers' Beliefs

Teachers' attitudes towards value, expectancy, and innovation are the key factors affecting their choice, their performance, and their persistence in implementing the curriculum (Abrami et al., 2004; Kay, 2006; Wilson et al., 2002).

Teachers' values directly their influence performance, activity choice, and participation in such activities (Eccles, 2005). Value for teachers indicates the usefulness (Graham & Taylor, 2002) or attractiveness (Wigfield, Tonks, & Eccles, 2004) toward a specific activity. The teachers' values can be measured by the benefits or usefulness of the program to teachers and students (Abrami et al., 2004; Wozney, Venkatesh, & Abrami, 2006). Also, a specific educational activity is more likely to be implemented if teachers perceive that it has high value (Abrami et al., 2004; Kay, 2006). Technology teachers' beliefs about the value of biotechnology instruction can be a significant predictor of whether biotechnology instruction is implemented. Biotechnology is important today because its content is essential for students' understanding of the world now and in the coming years (ITEA, 2000; Savage & Sterry, 1991; Scott et al., 2006; Wells, 1994). In other words, teaching biotechnology is valuable because it enhances the technological literacy necessary for students' lives in the future. Moreover, teaching biotechnology is important because biotechnology knowledge is significant for food, health, and environment of the world's population (Wells, 1994).

Another possible predictor for the implementation of biotechnology instruction is teachers' expectancy. Teachers' expectancy for success directly predicts their outcomes such as their performance, persistence, and choice of activities (Eccles, 2005). These expectations for success are strongly associated with teachers' ability to perform the assigned tasks and activities (Wigfield et al., 2004). Thus, technology teachers' beliefs about their ability regarding biotechnology instruction affect the implementation of such content. In other words, technology teachers' expectations for success in teaching biotechnology promote the choice or intent to implement this instruction.

Lastly, despite a strong national curriculum, the implementation of technology education has been dependent on technology teachers' beliefs about curriculum innovation (Yi & Kwon, 2008). Therefore, the choice or decision to teach biotechnology content also may be affected by Korean technology teachers' beliefs about innovating the current technology curriculum.

Research Questions

The purpose of the study was to investigate Korean technology teachers' beliefs related to their intent to implement biotechnology teaching. More specifically, the study attempted to answer the following research questions:

1. Do Korean technology teachers perceive biotechnology to be of value within technology education?

2. What do Korean technology teachers' expect from teaching biotechnology in their classrooms?

3. Do Korean technology teachers see the need to develop the current Korean technology curriculum to accommodate biotechnology instruction?

4. What is a predictive model for the dependent variable of the Korean technology teachers' intent to teach biotechnology when the following independent variables are considered: Korean technology teachers' demographic information, their perceptions of innovation in the biotechnology curriculum, their expectancy for biotechnology teaching, and their perceived value of biotechnology teaching?

Methods

Participants

The participants of the study were 114 technology teachers who were teaching technology as a part of the *"Technology-≠Home Economics"* subject in Korean middle schools located in two major cities (Daejon Metropolitan City and Seoul Special City) and one rural area (Gyeonggi Province).

The study adopted both random sampling and convenient sampling methods. The random sampling following Cochran's (1977) guidelines was employed to select technology teachers in Daejon Metropolitan City. A total of 95 technology teachers from a possible 127 teachers teaching in middle schools during the spring semester of 2008 were selected using Cochran's formula. From these 95 teachers, 46 participated in the survey.

The study also made an effort to reduce selection bias caused by location (i.e., metropolitan/city or rural areas). Using technology teachers' directories of four local districts in Seoul Special City and Gyeonggi Province, this study chose 75 middle school technology teachers and received responses from 68.

Instruments

The instrument consisted of five sections: 1) technology teachers' intent to implement biotechnology teaching (*intent:* 6 items); 2) technology teachers' perceived beliefs about biotechnology teaching as valuable (*value:* 8 items); 3) technology teachers' perceived beliefs about biotechnology teaching as expectancy (*expectancy:* 6 items); 4) technology teachers' perceived beliefs about biotechnology teaching as needs for innovation (*innovation:* 6 items); and 5) demographic information (e.g., years of teaching technology, college major, gender, and courses taken associated with biotechnology content in the technology teachers' preparatory institute).

Constructs. The dependent variable of the study was the technology teachers' intent to implement biotechnology instruction (*intent*) measured by six items.

The three components, *teacher value, expectancy,* and *innovation*, served as the major independent variables for the study. The items of teacher value and expectancy were developed based on definitions by motivation theorists (Eccles, 2005; Graham & Taylor, 2002; Wigfield, et al. 2004), whereas teacher innovation was created by following the suggestions for innovating the Korean technology curriculum (KICE, 2002; Yi et al., 2006). More specifically, value is defined as "intrinsic interest," "importance," and "usefulness," while expectancy is defined as "beliefs about ability" (Eccles, 2005; Graham & Taylor, 2002).

The degree of agreement for each item of the independent and dependent variables was measured by selecting one of the following responses for each item: strongly disagree: 1; disagree: 2; neutral: 3; agree: 4; Strongly agree: 5. The study included the "neutral" category to encourage respondents to make a response, instead of not responding (Bognar, 1997), although several researchers have found that respondents are more likely to choose the "neutral" category, and this can make a difference in responses.

Content validity. The instruments were reviewed for content/face validity by a panel of experts made up of two technology education scholars who hold doctoral degrees in the field of technology education. To overcome potential problems caused by translation, three Korean language teachers and two English language teachers from South Korean high schools reviewed the survey items.

Reliability of constructs. The researchers first conducted a pilot study using 21 participants from 10 technology middle schools who were not randomly selected and who had taught biotechnology for at least three years. The participants of the pilot study were asked to complete and comment on the web-based survey. In the pilot study, the reliability statistics measured by the Cronbach's alpha for expectancy, value, innovation, and intent ranged from 0.85 and 0.87. Corrections as suggested by pilot study participants were made to the total survey.

In the main data collection, the reliabilities (Cronbach's alpha) of teachers' belief of *expectancy, value, innovation*, and *intent* were measured at 0.889, 0.876, 0.843, and 0.888 respectively. For further statistical analysis, we conducted factor analysis for the three components.

Demographics. The study also collected demographic data (e.g., teaching experience measured by years of teaching, gender, major, and courses taken in the technology teachers' preparatory institutes). The years of teaching technology were divided into 8 categories (1 = less than 1 year; 2 = 1-3 years; 3 = 4-6 years; 4 = 7-10 years; 5 = 11-15 years; 6 = 16-20 years; 7 = 21-25; 8 = over 26 years).The courses related to biotechnology content at the teachers' preparatory institute were measured according to six categories: agricultural technology, environmental science/engineering, genetic engineering, food science/engineering, biology, and general science.

Data Collection

Both randomly selected and conveniently selected teachers were sent a web link to access a web-based survey, *"Korean Technology Teachers' Perception toward Biotechnology Teaching",* which was developed by the researchers, and included corrections based on the pilot study. Technology teachers (95) from the teachers' directory of Daejon Metropolitan City were used to select teachers randomly; 75 technology teachers from Seoul Special City and Gyeonggi Province were used to select teachers conveniently. An e-mail (including a link to the online survey and a cover letter) was sent to each selected teacher asking the teacher to complete the survey. This study was approved by the Virginia Tech School Institutional Review Board (IRB).

Results

Demographic Information

A total of 114 respondents (58.8% male and 41.2% female technology teachers) completed the survey instrument, with a total response rate of 67.5%. The missing data were replaced by the total means of each variable to capture all possible information without affecting the analysis results. The majority of respondents (n = 101, 88.6%) were technology teachers who had majored in technology education. About 11.4 percent of respondents (n = 13) had majored in "Home Economics," "Industrial Subjects," or "Agricultural Science."

Approximately 32 percent of the respondents had taught content relating to biotechnology for 7 to 10 years. Most of the respondents (73.7%, n = 84) took agricultural technology courses in the technology teachers' preparatory institutes as well. However, there were other courses required for technology teachers' preparatory work, such as environmental science/engineering (18.4%, n = 21), genetic engineering (23.7%, n = 27), food engineering (18.4%, n = 21), biology (38.6%, n = 44), and science (23.7%, n = 27).

Factor Analysis

The study performed a series of factor analyses to confirm interrelationships among items of each of the four components (*expectancy, value, innovation, and intent*). As presented in Table 2, most of the items of each component displayed high factor loadings. Through this process, one item, *"Q6: I am interested in reading newspapers and books and watching TV programs related to biotechnology"* indicated a cross-loading for value and expectancy (.301 for value .343 for expectancy), and thus it was removed from the survey.

Descriptive Statistics and Correlations among Variables

Table 3. presents the means, standard deviations, and correlation coefficients for the variables of *intent, value, expectancy, innovation,* years of teaching, number of courses in biotechnology content, and gender.

The respondents' composite mean of perceived value for teaching biotechnology was 3.92 on a five-point Likert scale, indicating that they perceived that biotechnology and its instruction was useful. The composite mean of expectancy for teaching biotechnology was 3.26

Table 2. Independent/Dependent Variables and Factor Loadings

Factors	Predictor Variables	Loading
Value (_=.889)	I believe that human life will improve through biotechnology	.781
	Biotechnology is one important content that should be taught in TE classes	.781
	Considering students' future life, learning biotechnology is essential	.778
	I like to teach biotechnology content	.756
	I believe that teaching biotechnology is valuable, considering the developmental trends of contemporary technological society	.748
	I am interested in learning new terminologies and concepts of biotechnology	.742
	Considering students' actual life, learning biotechnology is useful	.731
	I believe that all literate people should know biotechnology content	.690
Expectancy (_=.876)	I can implement problem-based learning in biotechnology instruction	.821
	I can develop hands-on activities related to biotechnology for TE classes	.813
	I can employ the content or strategies of other subjects (e.g. biology, mathematics, etc) for teaching biotechnology in TE classes	.789
	I can manage materials, tools, equipment, and the laboratory for biotechnology hands-on activities	.778
	I can evaluate/assess hands-on activities in biotechnology instruction	.774
	I can teach biotechnology in a unique method different from that of biology and agriculture teachers	.752
Innovation (_=.843)	We should employ biotechnology topics in motivating students	.858
	We should emphasize hands-on activities and practice, providing students with practical experiences	.820
	We should add the topics dealing with social/environmental impact as major content in biotechnology curriculum	.806
	We should eliminate simple cultivation technology and cover a variety of biotechnology topics	.766
	Developing more practical problem solving ability should be one of major goals teaching biotechnology **for** TE classes	.724
	We should emphasize the affective domain students (developing the attitude toward biotechnology)	.542
Intent (_=.888)	I will develop hands-on activity for my biotechnology teaching	.874
	I will acquire materials, tools, and equipment for biotechnology teaching	.837
	I will recognize the content of the textbook to teach biotechnology	.813
	I will build up knowledge and competency related to the biotechnology content	.802
	I will apply student based hands-on activities for biotechnology teaching	.801
	I sincerely teach biotechnology content in my class	.674

Table 3. Descriptive Statistics and Correlations of Variables

Variables	M	SD	1	2	3	4	5	6
1. Intent	3.938	0.654	-					
2. Value	3.921	0.574	.676**	-				
3. Expectancy	3.261	0.680	.681**	.536**	-			
4. Innovation	4.149	0.570	.541**	.426**	.336**	-		
5. Teaching yr	4.030	1.436	-.331**	-.290**	-.155	-.264**	-	
6. Courses	1.960	1.088	-.032	-.042	.088	-.122	.187*	-
7. Gender	1.410	0.493	-.076	.076	-.238*	.118	-.182	-.288**

*p<.05, **p<.01.

on the same scale, indicating a comparatively lower worth than *value*. In terms of changes to Korean technology education, teachers perceived that several aspects of the current biotechnology curriculum were in need of development: (1) Biotechnology content in technology education must be changed into more interesting topics to motivate students; (2) the current Korean technology curriculum must be reorganized into problem-based learning or hands-on activities; and (3) the biotechnology curriculum should avoid the topics of simple cultivation technology and should employ a variety of biotechnology topics.

The intercorrelations revealed that Korean technology teachers' intent to teach biotechnology was significantly associated with *value, expectancy,* and *innovation* (676, .681, and .541, respectively). A significant negative correlation was noted between the intent and teaching years (-.331). In other words, technology teachers who had taught for a longer time were less likely to want to teach biotechnology.

Teacher Intent to Implement Technology Education

Overall, Korean teachers indicated a willingness to teach biotechnology, having a mean of intent of 3.938 on a five-point Likert scale. An ANOVA was conducted to compare the degree of teachers' intent to teach technology education among the three locations of Seoul, Daejon, and Gyeonggi, and there was no significant difference ($F = 2.877$, $p > 0.05$), as shown on Table 4. This finding was further verified when data were analyzed using Levene's test (0.614, $p > 0.05$).

developed by the authors was administered, to 114 Korean middle school technology teachers who had been selected using random and convenient sampling methods from three different districts. An ANOVA was used to check the difference of teacher intent, which could be caused by different sampling methods and locations; however, no significant difference was noted ($F = 2.877$, $p > 0.05$).

Korean technology teachers saw the benefits of biotechnology in their students' lives and the need to teach biotechnology content in technology education class. However, their belief in their ability to teach biotechnology content

Table 4. Analysis of Variance Summary Regarding Teachers' Intent

	Sum of Squares	df	Mean Square	F
Between Groups	2.389	2	1.194	2.877
Within Groups	46.070	111	.415	
Total	48.459	113		

Factors for the Intent to Teach Biotechnology Content

The major tool of the study was the hierarchical multiple regression with which the effects of independent variables can be examined step by step after controlling for the effects of demographic variables. The analysis model first controlled for the effect of teacher gender, years of teaching, and number of courses; then v*alue, expectancy, and innovation* were added to the model, one by one, as presented in Table 5.

The results show that three independent variables (teachers' ***value, expectancy, and innovation***) successfully predict the dependent variable (the intent to implement biotechnology teaching), which is indicated by F-value of 34.929 ($p < 0.01$) and R-square of 0.664. When the contribution of each independent variable was added, Korean technology teachers' value was found to be a significant predictor in this model. The coefficients of teachers' value (•, = .726, p < 0.01), expectancy (•, = 0.411, $p < 0.01$), innovation (•, = .278, $p < 0.01$) were significant, and this was also verified by the significant Pearson's correlation coefficients ($r = 0.681$ $p < 0.01$; $r = 0.676$, $p < 0.01$; $r = 0.541$, $p < 0.01$, respectively).

Summary and Conclusion

This study used an online survey to investigate Korean technology teachers' beliefs (value, expectancy, and innovation) associated with their intent to teach biotechnology content in technology education classes. The piloted survey

successfully was not consistent with their level of perceived value of the subject. The survey results suggested that the teachers believed that the current biotechnology curriculum within Korean technology education should be developed in terms of learning topics, instructional strategies, and a variety of hands-on activities. In particular, they wished to teach a variety of biotechnology topics through problem-based learning or hands-on activities.

The major finding of the study was that Korean technology teachers' beliefs as measured by value, expectancy, and innovation were significantly correlated with teacher intent to implement biotechnology in their classrooms. Hierarchical multiple regression model successfully predicted their intention to teach biotechnology content after controlling for demographic information (years of teaching, courses, and gender).

In addition, the study discovered that those technology teachers who had taught longer were less likely to teach biotechnology content in their classes.

Implication

There are several implications for future practice and for studies that should be conducted. As stated previously, the results of this study suggest that technology teachers face a lower expectancy level than the value they place on technology education. This finding may

Table 5. Hierarchical Multiple Regression Analysis Summary (N=114)

Variable	B	SEB	_	R2	_R2
Step 1				.124**	
Years of Teaching	-.159	.042	-.348		
Courses	-.004	.057	-.007		
Gender	-.188	.125	-.141		
Step 2				.497***	.374***
Value	.726	.081	.637		
Step 3				.619***	.122***
Expectancy	.421	.072	.438		
Step 4				.664***	.045***
Innovation	.278	.074	.243		

Predictor Variable: Teacher intent to teach biotechnology
***p<0.001

highlight the need to improve their expectancy level toward biotechnology and its instruction. In particular, these teachers show strong motivation to innovate current biotechnology curriculum for technology education classes. Professional development programs emphasizing biotechnology and its instruction can help technology teachers to improve their competency level (Daugherty, 2005; Scott et al., 2006). This study recommends that biotechnology content should be delivered systematically during technology teachers' professional development.

In addition, this study concentrated on investigating technology teachers' attitudes and motivation toward biotechnology and its instruction. However, there may be other variables affecting biotechnology instruction for technology education programs. External factors such as school support, facilities, and equipment can affect biotechnology instruction (Brown et al., 1998; Daugherty, 2005). Also, the sample of this study was middle school technology teachers in South Korea. In this country, technology education is a compulsory subject under the national curriculum, and biotechnology content is part of technology education presented at the middle school level. Therefore, future studies should investigate the beliefs of technology teachers in other countries including related external factors.

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Examining the Nature of Technology Graduate Education

Nathan Hartman, Marvin Sarapin, Gary Bertoline, and Susan Sarapin

Introduction

According to the Association of Technology, Management, and Applied Engineering (ATMAE), graduate-level studies in technology are designed to prepare technologists to focus on the applied challenges of society, industry, and government through integration- and implementation-oriented activities (2009). Although the association's affiliated institutions and membership have been interested in research and graduate education for many years, increased discussion is needed concerning both the goals and delivery of graduate programs leading to master's and doctoral degrees related to the field for the 21st century. Many of the academic participants in this organization, as well as others, work at universities that include a College of Technology (COT) or similar department-level entity associated with applied engineering, management, or industrial technology. Many of these organizations are currently examining their research and engagement efforts in light of the currently shrinking state and federal budgets and an increasing demand on the part of faculty and students for resources to conduct research. As such, these institutions are exploring ways to align strategic plans with university, state, and federal objectives. They are trying to engage industry in a manner that provides value to both parties. All of this is taking place in an environment where future funding streams and organizational infrastructures are uncertain. In order to promote confidence in the academic research agenda of technology-based programs, a clear vision for research and engagement efforts in technology disciplines is necessary.

The authors advocate a definition of research activity and strategy that includes traditional funding sources for research, as well as a fresh look at how an engaged graduate program in a technology discipline would function. The strategic plans for both the university and the college where these authors are employed revolve around the following mission: serving the citizens of the state, the nation, and the world through discovery that expands the realm of knowledge; learning through dissemination and preservation of knowledge; and engagement through exchange of knowledge. A major goal of a technology department or college should be to further develop graduate education in fulfillment of this vision.

Presently at the authors' institution, the COT is going through a process of implementing individual master's degrees in the academic areas of each technology department in the college while continuing to deliver the Ph.D. in Technology at the college level. Such work has caused the technology graduate faculty to (a) formulate the role of graduate education within the context of the larger university community, and (b) articulate how graduate education in technology may differ from that of the other colleges and schools in the academy. While the authors acknowledge that the depth and breadth of implementation of the suggested research activities in this article will vary among institutions, it is hoped that any technology-based department or college could generalize this approach to advance graduate education at its institution.

The purpose of this paper is twofold. This work presents a general discussion of the theoretical foundation for graduate education in technology followed by specific applications of research activities within graduate education in technology. This paper represents the authors' view of the role of graduate education in (a) advancing the knowledge base, (b) adapting a research paradigm, (c) preparing the future Technology faculty, (d) capitalizing on the research interests of the faculty, (e) addressing industry's challenges in implementing and adapting technology, and (f) structuring graduate education in technology.

Advancing the Knowledge Base

Discovering, integrating, applying, communicating, and teaching the knowledge of doing are integral to undergraduate and graduate education for professions in technology, where technology is defined as those fields that apply practical knowledge in improving the human condition. A typical undergraduate technology program is based more on students' initial acquisition of knowledge and skill within the technical areas under study, graduate technology education is based more on developing students' abilities and achievements in scholarship. Boyer (1990) presented a model encouraging active participation in a wide range of scholarship for the higher education community, including the Scholarship of Discovery, the Scholarship of Integration, the Scholarship of Application, and the Scholarship of Teaching. Such a model is particularly salient in identifying the goals of technology graduate education. In a research-intensive university environment, these attributes cannot be demonstrated in a coursework-only graduate program. Graduate programs at such institutions require a student-specific degree plan of study that provides learners with the requisite experiences to acquire knowledge and skills needed for graduate students to develop focused research agendas. The plan of study should be a well-thought-out regimen of coursework enabling the learner to demonstrate scholarship by the completion of a directed project, thesis, or dissertation used to investigate and report on a significant undertaking in discovery, integration, application, or teaching related to technology.

Adapting a Research Paradigm

Central to identifying the mission of graduate education in technology is the articulation of the appropriate domains of inquiry. Bush's (1945) work titled Science:The Endless Frontier presented a linear model representing the post-World War II view that discovery in science gives rise to applications in technology. Based on this model, the domains of basic research and applied research are seen as independent and almost unrelated. Whereas basic research is conducted by "scientists" for the sole purpose of understanding the nature of phenomena, applied research is conducted by "technologists," and it is directed solely at solving societal problems. Stokes (1997) presented a more robust model for the domains of inquiry, which can become the research paradigm for technology graduate education. This model considers the desire of investigators to undertake the quest for basic understanding and the consideration of the use of research and inquiry. The mission for discovery, integration, application, and teaching in a COT context can be identified in a model adopted from Stokes' (1997, p. 73) four-quadrant graphic shown in Figure 1.

Research is inspired by whether it promotes understanding of the fundamental elements of a discipline and whether there is further utility to

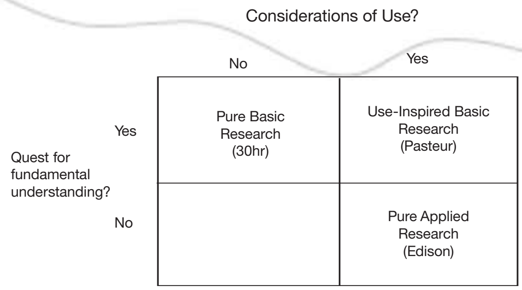

Figure 1. Quadrant Model of Scientific Research

the research results once they are known. Research in its pure, basic form known to other disciplines (e.g., physics, biology, chemistry) does not typically occur in technology disciplines mainly because of the mission of technology-centric education and research in general. However, use-inspired basic research and pure applied research are more common, and these can define that nature of scholarship in technology graduate programs. This focus is not on fundamental scientific behavior, but rather on applied usage of basic science and extension and validation of novel tools and techniques.

Preparing Future Technology Faculty

Demographic surveys conducted by Zargari and Sutton (2007) document the need for institutions offering technology degree programs to have a well-qualified faculty. Their survey demonstrates the need for providing graduate education leading to the terminal degree in the field because attaining such degrees is an important criterion in hiring, awarding tenure, and promoting technology faculty. Doctoral programs specific to technology are limited, creating a need that must be addressed as undergraduate programs in technology continue to grow. The work of Golde and Walker (2006) provides a paradigm helpful for identifying the goals of graduate education in technology in preparing the future stewards of the technology disciplines. According to their view, "a steward of the discipline considers the applications, uses, and purposes of the discipline and favors wise and responsible applications" (p. 13). Well-thought-out and delivered graduate programs in technology should focus on increasing productivity in the scholarship of discovery, integration, application, and teaching for the professions in technology. Such learning is often developed through a mentoring process where graduate students work closely with their major advisor pursuing discovery, learning, and engagement projects. Scholarship in technology that focuses on discovering methods for extending the state of the art (integrating cutting-edge tools, techniques, and methods) expands the literature in the field. Applying this knowledge in business and industrial settings, and improving technology teaching as a result of graduate education contributes to the field and will help address the faculty needs of future technology programs in the colleges and universities in the nation.

Capitalizing on Faculty Research Interests

College and university faculty members who are heavily engaged in research behave in a fashion similar to independent entrepreneurs who seek funding through grants to advance their research agenda. Much of the funding they secure is used to hire graduate students to engage in research work, which leads to student theses, directed projects, and dissertation topics. This work is disseminated through conference presentations and publications; often it leads to further research opportunities. This cyclical process, when implemented strategically, results in focused recruiting of graduate students into a program, funding to support graduate students, scholarly publications, course development, and advances in the application of technology. Prospective graduate students who are interested in becoming part of this entrepreneurial-scholarship model should find the work of Baylor, Ellis, and Redelfs (2000) to be a helpful resource in choosing the appropriate institution and program. Although these authors were not writing about graduate education in technology, their work is helpful for all prospective graduate students seeking an institutional match for their professional development. The following questions posed by these authors (p. 7) are important:

- Does the faculty exhibit special strengths and research qualities through their graduate advisees, published works, and funded research?
- Are the libraries, laboratories, computers, and other research facilities adequate for your educational needs?
- How senior are the professors in your area, what are their interests, and what will their availability be?
- Does the department of interest offer a sufficiently large and varied curriculum to allow you a broad offering of courses and options?
- What are the degree requirements? Number of hours of coursework required? Major exams? What are the expectations for a thesis or dissertation?
- How long will it take to complete the program?
- What is the completion rate of the general graduate population?
- Is there funding available in the form of teaching or research assistantships?

Addressing Industry's Challenges Implementing and Adapting Technology

It is well documented that industry faces a shortage of technical talent in the areas of engineering and science due to increasing competition from foreign states and the decreasing enrollment of domestic students into those fields at our own universities (Keating et al., 2005; Jackson, 2003). One of the key questions that many people within research universities, and specifically within technical domains, ask is how can a contemporary university partnership with an industry partner effect change and have an impact on industrial processes without changing the fundamental role of the university? The literature suggests that the fundamental nature of that relationship would not change the role of the university, but rather it could strengthen the bond between the corporate world and academia, as well as provide meaningful experiences for students at all levels. Because many large research institutions are also land grant universities, and there is at least one land grant university in most states, readers need to look no further than that model to draw inspiration for what is being proposed.

According to the United States Library of Congress Web site (2008), the original mission of a land grant college was to provide higher education opportunities for the citizens of a particular state, especially in the areas of agriculture and the mechanical arts. By design, a set of public universities was given a charter that included engagement with industry for the betterment of society. However, over time this has evolved into an enterprise of sorts as universities compete for industrial and federal funding to support research initiatives, which are often driven by regional economies or federal defense and energy agendas (Kennedy, 1995).

Complimentary to this larger federal initiative, Boyer (1990) has suggested a revised role for the universities based on several factors, including faculty compensation and incentives. One facet to his approach has been to delineate scholarship in certain areas: discovery, integration, application, and teaching, and the premise is that excellence in these areas by faculty makes for a more holistic experience for students and a more productive working environment. So how does this relate to graduate education and research at large universities? In the COT, the notion of the scholarship of application would likely be considered engagement-—with industry, federal agencies, education, or the community. It would involve bringing the intellectual resources of the university to bear in solving an applied problem that has affected the constituents or partners of the university. In the case of engagement with industry, this would likely mean funded activities to solve a specific problem.

The most expeditious method for doing this type of work is to have teams of undergraduate and graduate students funded to work on engagement projects. In a technology discipline, giving graduate students a thesis project that has real-world applications is ideal. It provides them an applied scenario upon which to direct their efforts, and it is more in line with their coursework than something that is rather esoteric in nature. However, the results of these activities may or may not be available externally because of intellectual property issues or federal controls, which should be carefully negotiated before the project commences. Although this secrecy of results may not coincide with the tenets of the original land grant mission, it is certainly a reality in the contemporary economic climate.

Even though engagement work with industry partners can contribute to the learning and maturation of graduate and undergraduate students, the university can also provide ongoing professional education to the incumbent workforce, which is also in line with the mission of a land grant university. Practicing professionals in technical disciplines struggle to keep pace with changing technology in light of their job requirements, and universities with technical- and technology-based degree programs can address the need for professional education (Dunlap et al., 2003; Keating et al., 2005) through the applied nature of the curricula. In doing so, technology departments could address the ongoing training and education of engineers, technologists, and managers from entry-level positions through senior managers and directors by providing coursework that deals with project management, measurement and analysis, training and human resource development, as well as many technical areas, depending on the company and faculty involved. These professional programs may best be delivered in non-traditional ways through distance education, weekend programs, or other hybrid delivery methods. It is also possible to develop a professional program that can become revenue-generating, which can be invested in both the traditional and professional graduate programs.

Table 1: Graduate Student Expected Outcomes (Purdue University College of Technology, 2007)

Each graduate student should be able to:
Envision, plan and conduct research and development activities;
Identify, comprehend, analyze, evaluate and synthesize research;
Evaluate technologies and technology-related programs;
Assess individual performance with, and understanding of, technology;
Communicate effectively and employ constructive professional and interpersonal skills; and
Function effectively in one or more of the technology disciplines.

Structuring Graduate Education in Technology

Based on the discussion of scholarship in technology, the graduate faculty at the authors' institution have identified a range of student outcomes. The outcomes, presented in Table 1, are helpful in communicating student expectations in technology graduate education and in providing a foundation for assessing the quality of the program.

Documenting the expected student outcomes is not only important for internal quality control but also for serving as the foundation for specialty and regional accreditation. Accreditation is paramount for the institution's credibility. Standards identified in resources such as the Handbook of Accreditation (2003) of the North Central Association–Higher Learning Commission require programs to identify and document student attainment of such outcomes similar to Table 1. Recently, the Association of Technology, Management, and Applied Engineering Board of Accreditation was granted permission by the Council on Higher Education Accreditation (CHEA) to accredit master's degree programs in addition to associate and baccalaureate degrees (Eaton, J., personal communication, May 4, 2009). The authors of this article predict the number of institutions undertaking such specialty graduate program accreditation will increase.

Master's-level COT graduate students are given the option of conducting a directed project ora thesis using an on-campus or a weekend model to demonstrate attainment of the program's learning outcomes. On-campus students are typically funded as graduate teaching or research assistants while weekend students typically work in industries related to the COT and receive a combination of at-the-workplace and on-campus instruction. According to the handbook for the Master's of Science degree at the authors' institution (Purdue University College of Technology, 2006):

> The directed project is an applied research project that is more extensive and sophisticated than a graduate-level independent study and less formal than a master's thesis. The overall objective of the requirement is to engage each graduate student in a study, typically industry or business focused, which is sufficiently involved as to require more than one semester to conceive, conduct, and report. The focus is to be placed on a topic with practical implications rather than original research. In so doing, the project should reflect the mission of the College of Technology by advancing technology through developmental research, innovation, and invention. (p. 8)

Graduates who wish to conduct more formal inquiry, or who intend to pursue a doctoral degree after completing the master's degree are encouraged to follow the thesis option to demonstrate the program's learning outcomes. The Handbook (2006) provides the following explanation of a thesis:

> A Master's thesis in Technology is a significant piece of original work, typically involving research, a formal written description of that research, and an oral defense of the research. It should contribute new knowledge to the discipline, but will include an extensive review of what others have contributed to the topic as well. The tone should be scholarly, with a primary audience of other researchers (p. 9).

COT doctoral students demonstrate achievement of the learning outcomes by completing coursework designed to further develop their scholarly abilities and by completing a Ph.D. dissertation that is a significant piece of original work conducted by the student under the direction of an appropriate graduate faculty committee, resulting in scholarship of discovery, integration, application, or teaching that contributes to the knowledge base of the field. Technology Ph.D. recipients pursue careers in higher education, business, industry, and government – regionally, nationally, and internationally.

In addition to the nature of technology graduate student research, a particular set of coursework is critical in achieving these research objectives and learning outcomes. It will provide a foundation upon which students build their research objectives. This coursework is also important in developing a suitable graduate to serve and engage industry in solving challenges with technology. Courses that would be critical in accomplishing this mission would include the following:

- Research Methods
- Data Analysis Techniques
- Project Management
- Global Technology Issues
- Ethics and Technology
- Integration and Implementation of Technology

Research methods and data analysis are important so students can make decisions while conducting research process and executing the project. Background in project management would be somewhat tailored to a specific technology domain; however, topics such as budgets, goals and objectives, and personnel selection can be common to all domains. The effect of technology on a global society has become increasingly important as commerce, academics, and government transcend national borders, and the impact that technology has regarding ethical decision making is important for both accepting and implementing that technology. The topics of implementation and integration help students to understand the effects that technology can have on people, systems, and organizations, regardless of the technology domain in question. Although this list of courses is not comprehensive, it can provide a foundation for many academic institutions to implement.

Conclusion

The work of Applegate (2002), titled Engaged Graduate Education: Seeing with New Eyes, offers inspiration that can be applied to graduate education in technology when the author discusses the role of three important attributes for improving higher education, namely vision, passion, and action (p. 4). The vision for technology graduate education presented in this article was centered on the scholarship of discovery, integration, application, and teaching. COT graduate students and faculty are challenged to pursue this scholarship with passion, thus improving undergraduate and graduate education for the professions in technology, integrating the unique contributions of technology into the academic institutions while contributing to the further development of the knowledge base in the field. Finally, a commitment to action is needed. Such actions can include technology professionals' commitment to continue process improvement in education, lifelong learning, and scholarly productivity in the field. Graduate students and academics in technology can facilitate this action by developing and pursuing clear agendas for the scholarship of discovery, the scholarship of integration, the scholarship of application, or the scholarship of teaching.

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The 2008 Paul T. Hiser Exemplary Publication Award Recipient

Sophia Scott

"Perceptions of Students' Learning Critical Thinking through Debate in a Technology Classroom: A Case Study"

The Board of Editors of The Journal of Technology Studies and the Board of Directors are pleased to announce the recipient of the Paul T. Hiser Exemplary Publication Award for Volume XXXIV, 2008.

The Board of Directors established this award for deserving scholars. In recognition for his exemplary service to the profession and to the honorary as a Trustee and Director, the award bears Dr. Hiser's name. It is given to the author or authors of articles judged to be the best of those published each year in this journal.

Selection Process

Each member of the Editorial Board recommends the manuscript that he or she considers the best of those reviewed during the year. The board nominates articles based on their evaluation against specific criteria. A majority vote of the editors is required for the award to be made. The honor society's Board of Directors renders final approval of the process and the award.

Criteria

1. The subject matter of the manuscript must be clearly in the domain of one or more of the professions in technology.

2. The article should be exemplary in one or more of the following ways:
   - Ground-breaking philosophical thought.
   - Historical consequence in that it contains significant lessons for the present and the future.
   - Innovative research methodology and design.
   - Trends or issues that currently influence the field or are likely to affect it.
   - Unique yet probable solutions to current or future problems.

A $300 award recognizes the recipient(s) for the year and is presented during an Epsilon Pi Tau program at an annual professional association conference.

GUIDELINES FOR The Journal of Technology Studies

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SUBJECT FOCUS

The JOTS welcomes *original* manuscripts from scholars worldwide focused on the depth and breadth of technology as practiced and understood past, present, and future. Epsilon Pi Tau, as perhaps the most comprehensive honor society among technology professions, seeks to provide upto-date and insightful information to its increasingly diverse membership as well as the broader public. Authors need not be members of the society in order to submit manuscripts for consideration. Contributions from both academics and practitioners are equally welcome.

A general guide to the breadth of topics of potential interest to our readers can be gained by consideration of the 17 subclasses within "Technology" of the classification scheme of the Library of Congress, USA <lcweb.loc.gov.catdir/cpso/lcco/lcco_t.pdf>. This includes engineering and allied disciplines, informatics in its many manifestations, industrial technology, and education in and about technology. Authors are strongly urged to peruse this list as they consider developing articles for journal consideration. In addition, JOTS is interested in manuscripts that provide:

- brief biographical portraits of leaders in technology that highlight the difference these individuals made in distinct fields of technology or its wider appreciation within society,
- thoughtful reflections about technology practice,
- insights about personal transitions in technology from formal education to the work environment or vice versa,
- history, philosophy, sociology, economics, and anthropology of technology,
- technology within society and its relationship to other disciplines,
- technology policy at local, national, and international levels,
- comparative studies of technology development, implementation, and/or education,
- industrial research and development,
- new and emerging technologies and technology's role in shaping the future.

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