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Ideology and Tactics for Engineering Education to Lead the Nanotechnology Revolution*

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Nanotechnology has finally emerged out of the intangible horizon into the general community, society and industry, regardless of the unprepared workforce to back up the drive. In this article, the author examines the ideology of this new technology, and elaborates on its multidisciplinary connections and interdisciplinary interactions with other preceding sciences and technologies, such as quantum physics, molecular chemistry, biotechnology, materials science and information technology, as well as its interactions with other meta-disciplines, including politics, culture, economy and education. Questions that need to be confronted include: Will this new technology continue to flourish and generate new economies or just dissipate? Will it bring hype or fear? In order to bring about positive answers to these questions, engineering education should play a key role in preparing a global workforce that is qualified in nanotechnology so as to lead this revolution of the 21st Century to a new enlightenment and profitable economy. The alternative will make countries less competitive. Behind this challenging task, a profound ideology that is enforced with effective strategies that link both the material world and the living world should be the driving power and guide. Although this is a global problem, limited data confines much of the article's discussion to the USA and Taiwan.

INTRODUCTION

Nanotechnology is here at the beginning of the 21st Century. It has taken more than 40 years of ambiguity and incubation to reach this dawn of the nanotechnology revolution. In January 2001, then President Clinton introduced the National Nanotechnology Initiative (NNI) at Caltech, USA, where Nobel laureate Richard Feynman prophesised back in 1959, *The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom … There is plenty of room at the bottom* [1][2]. Feynman's words were then expanded and crusaded by Eric Drexler in his book, *Engines of Creation, the Coming Age of Nanotechnology* [3].

So, what is nanotechnology? It is the technology dealing with the size of materials on the order of about 1-100 nanometer (nm), where 1 nm is 10^{-9} m and approximately 10 hydrogen atoms. Interestingly, the Greek origin for *nano* means *dwarf*, while in Chinese, nano is translated as 奈米(*naimi*) in Taiwan, which happens to mean *What do we do?* or *What's next?* This is fitting for today's public psyche about nanotechnology: *hype and fear*. A new acronym for NANO is introduced here: *N*ovel *A*pplications of *N*ature's *O*rder. Indeed, nanotechnology is a human mimesis of nature's ordered structure. Nature provides the best examples of molecular magic. Hopefully, this new concept of NANO will soon provide insight to those who embrace nanotechnology.

However, it is not just the small size of nanotechnology that is so attractive. There are several other unique features that deserve attention and investment, such as the following:

- The tremendously high surface to volume ratio makes nanomaterials highly chemically reactive,

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and therefore ideal as catalysts;

- Partly due to the *size effect*, and partly due to better *ordered structure*, nanomaterials are stronger than bulk materials by many orders of magnitude;
- The new manufacturing concept and technique based on the *bottom up* approach and *self-assembly* mechanism have opened up a totally new way of making materials efficiently and cheaply;
- The new world of quantum mechanics has enabled nanotechnology to climb high in scientific authority and social fascination;
- The interdisciplinary concert among biotechnology, quantum physics, information science and materials science has made nanotechnology stand out as the tangible and promising technology of today and tomorrow.

Any new technology, in order to flourish, requires the five I's, namely: *initiative*, *ideology*, *investment*, *intellect* and *infrastructure*. In this article, the author seeks to touch upon all the five I's, but with a greater focus on *initiative*, *ideology* and *intellect*. In other words, these three I's are where engineering education plays important roles. Particularly in Taiwan, notwithstanding the hype and hot response from the industrial and commercial sectors, the reaction from the educational sector has been far too indifferent and cold.

The huge amount of money pumped into Taiwan's top five national universities and the Industrial Technology Research Institute (ITRI) was specifically granted for *outstanding research activities* and industrial partaking. No incentives whatsoever have been initiated from the government for the teaching or education of nanotechnology. Any new technology will go astray and become short lived without strong initiatives and authoritative funding, a deep and inspired thought system (ideology), a massive workforce of high quality (intellect), and mature public support, as well as a strong industrial network (infrastructure). Engineering education is responsible for building up the first three I's, and also a part of the infrastructure or integration of curriculum, so as to lead the nanotechnology revolution.

THE INITIATIVE FOR NANOTECHNOLOGY

An anecdote of Feynman is worth telling here. In his historical lecture on nanotechnology in 1959 at Caltech, he bravely offered a prize of $1,000 (which is worth about $10,000 today) to anyone who could build *a rotating electric motor of "only 1/64 inch cube" (not including the lead wires) which can be controlled from the outside*. The challenge did not last a week, and the prize was won by an engineer named William Mclellan [4]. The prize of $1,000, although a small amount, could be thought of as the first initiative from a private sector for nanotechnology.

A strong initiative from government or private sectors always helps to advance a technology in its cause and rate of progress. It was in the early 1960s, right after the triumphant launch of the Sputnik satellite by then Soviet Union in 1957, that the USA was almost *pushed off the cliff* in terms of both scientific and political pride. President Kennedy soon took a brave and strong initiative: he announced the establishment of the National Materials Research Laboratories Initiative (NMRLI) in 1959, which endowed seven selected universities to build an interdisciplinary Materials Research Laboratory on each campus to attract materials scientists and engineers from all over the world. Indeed, such a national initiative saved the USA and helped it to gain leadership in space exploration.

Fast forward to 2000 when, after 2-3 years of contemplation and campaigning by the USA's National Science Foundation (NSF), the National Nanotechnology Initiative (NNI) was finally established. In January 2001, then President Clinton officially announced and kicked off the 21st Century with the establishment of the NNI. By 2003, the NNI had funded nearly $3 billion and inspired over 700 nanotechnology companies, with an estimated 1,000 by 2005. So, if Richard Feynman planted the seeds for nanotechnology some 40 years ago, then the US Government would be ploughing fields wherein private enterprises could sow the fruits [5].

Similar efforts and impetus has been exerted by other countries like Japan, whose government funding started in 1997 as $120 million, rose to $750 million by 2002, and is expected to reach a total of $4 billion by the end of 2005. The European Union (EU) has claimed a total funding of $1 billion by 2006 [6][7].

In Taiwan, the Government established the National Technological Program in 2002 to fund some national universities and research institutes. To date, the government initiative has funded about $200 million from 2002-2005, and should unleash $650 million by 2007.

Latecomer China has funded $40 million during its five-year plan (2001-2005). This figure may initially seem low, but it is potentially high considering China's low labour costs and intensive nano-activities in universities in recent years. According to a very recent report, China has boosted its output of PhDs in science and engineering by 14% a year, and universities in the USA award 25% of all their PhDs in science and engineering to Chinese citizens [8]. This implies not only a rapid growth of quality labour, but also a high potential of funding for nanotechnology in China.

A new initiative under the name of the Asian Pacific Nanotechnology Initiative (APNI), sponsored by members of the Asian Pacific Nanotechnology Forum, has been formed recently. Such a private initiative has claimed a funding of $1 billion in 2003 [9].

The initiatives in the USA, Japan and other countries are formed by a *top down* approach with centrally coordinated structures. In the USA, the NNI, for example, is supported by all taxpayers indirectly, and administrated by the Federal Government directly, through various government agencies, such as the NSF, DOD, DOE, NASA, NIH and NIST, as shown in Figure 1 [10][11].

Before moving to next section on the ideology, it is essential to point out the interplay among biotechnology, materials science and information technology; this is illustrated in Figure 2. Nanotechnology, information technology, materials science and the biosciences interrelate to produce new systems and concepts. Materials provide function and processing, and nanotechnology has enabled the construction of smart materials or systems with a scale-down and bottom-up processing. The combination of materials science with the life sciences, as well as information technology, which is missing in Figure 2, has *created* knowledge and materials obtained from living organisms to *synergise* a further integration of design concepts or constructs (biomimetics) to materials processing and to end products (smart systems and bionics), as shown by the curved and straight arrows in Figure 2 [12]. So, initiatives for nanotechnology could be funnelled indirectly through many other interrelated fields.

THE IDEOLOGY FOR NANOTECHNOLOGY

The word *ideology* has been more frequently used in the political and social arenas than in the scientific and technology occasions. In this article, as the technological revolution is being discussed, the author suggests that, in the course of pursuing a scientific research or technological project, the ideology (a common thought system) comes even before the other I's. This is especially the case for nanotechnology, which is quite different from other preceding technologies in

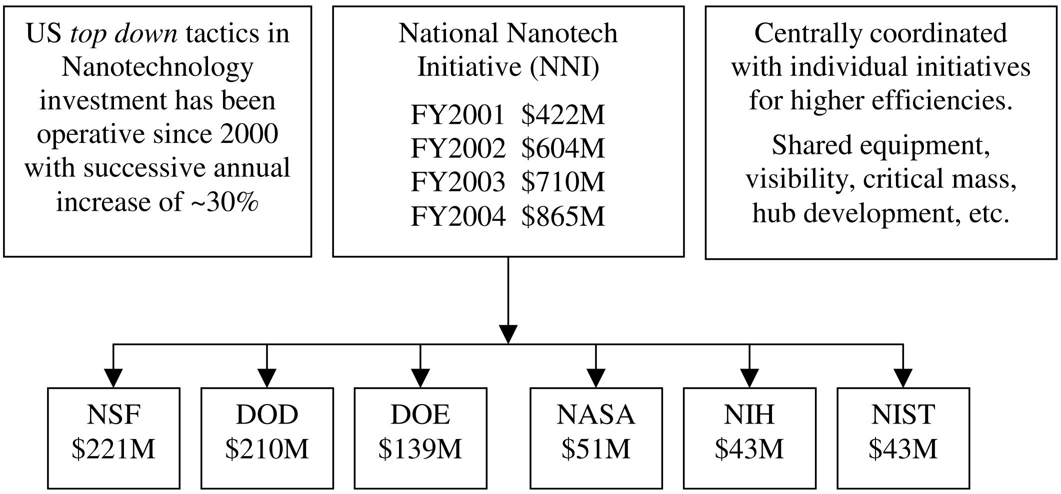

Figure 1: Structure showing the central coordination of the NNI and how it coordinates and allocates funding to six organisations and institutions [10].

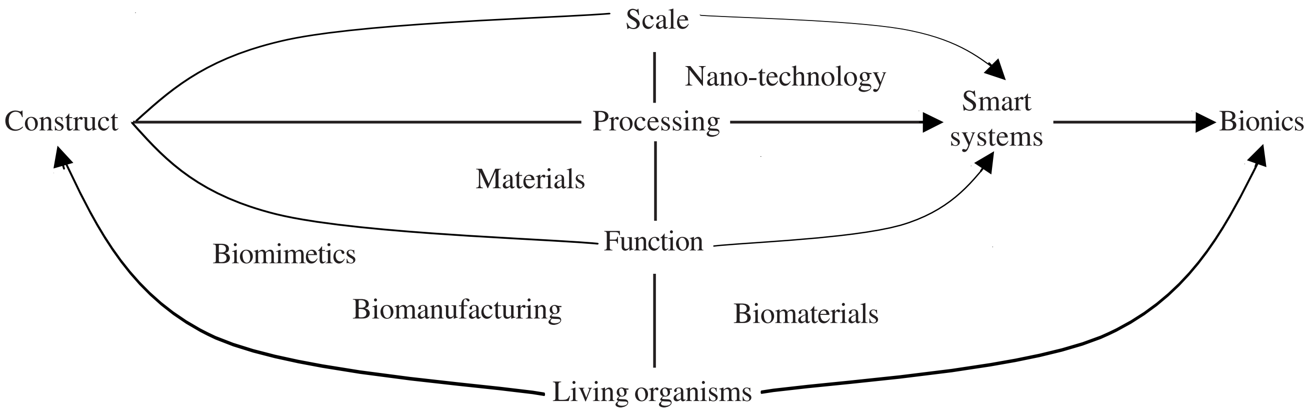

Figure 2: The synergistic interplay of technologies [12].

terms of its lack of technical definitiveness and public acceptance, a common and definite ideology should be agreed upon among scientists, engineers, investors and educators.

It is affirmed here that the ideology of nanotechnology is both technical/physical and meta-physical in nature. It touches upon the nature of individual atoms, as well as the behaviour and mechanisms of atomic or molecular assembly. Such biological and biomimetic connections bring nanotechnology very close to the core of the living world. The ideology of nanotechnology is built upon the simple belief that nature is the ultimate nanotechnologist. Humans may go beyond what nature can make, and come up some new hybrid materials and structures someday, but humans also need to keep their hands from disrupting their environment and biosphere. People have come to realise that nanomotors, nanomachines – even nanorobots – have existed in nature since the beginning of life. The rotating motors or turbines of only 12 nm diameter, much smaller than what Feynman has challenged, called Adenosine Triphosphate (ATPase), have virtually existed in every living cell for pumping and transmitting protons across the lipid membrane [13][14].

There are many other examples in nature like these nanoturbines that fascinate and convince humans to learn and mimic nature. Even before it is known how they work, one can be assured that the physics and chemistry are possible and, at least, some basic laws will not be violated in mimicking them. But, on the other hand, it must be remembered that nature has achieved all these myriad wonders without generating any toxic materials or pollutants, or depending on expensive machines and factories.

The ideology of nanotechnology also needs to take into account its interdisciplinary and multifunctional characteristics. As stated before, nanotechnology evolved from quantum physics, semiconductor processing technology, computer and information technology, advanced materials science, and biotechnology. Its core technical knowledge is much more complex than any of its predecessors. It is not a piece of invented hardware like the automobile, aeroplane, television set or semiconductor chip; it is an enabling technology ensuing out of several maturing technologies that all culminate towards the need for nanoscale structure, nanofabrication fineness, and quantum mechanical concepts. In other words, nanotechnology is characterised by the following:

- The *interdisciplinary* interplay of quantum physics, chemistry, biology, electronics and materials science;
- Its *intangible* nature when viewed from a single disciplinary angle;
- The *inevitable* convergence of its predecessors, reflecting a common demand of the human search for excellence and higher quality of life.

Here is introduced another three I's that are different from the previous five I's or three I's, and are the sub-ingredients of the ideology of nanotechnology.

The nanotechnology revolution in the materials domain will not only trigger more new adventures on information technology and biotechnology fronts, but will also make an additional impact on manufacturing skills, logistics and personal lives, and may even invade into the realm of ethical and environmental problems. The material world and the living world will encounter each other and may find connectivity through this nanotechnology revolution. It is hoped that such a connection of the two worlds will be a happy ending to human progress and destiny. However, it may also lead to catastrophic self-destruction, as Michael Crichton warns in his most recent fiction book, *Prey* [15]. Therefore, the ideology of nanotechnology or nanotechnology itself takes people to the living world, which includes the organisations of human society, namely: politics, education, economy and culture. Such interactions can be illustrated in a pyramidal diagram (see Figure 3).

The ideology for nanotechnology should go beyond the realisation of its wide interdisciplinary characteristics, and call for a solitary zeal and a purposeful commitment from all interacting disciplines. It is the responsibility of both governments and nanotechnology educators to induce such a social commitment. The strong promises of nanotechnology for a new enlightenment of human knowledge, a novel enhancement of living quality and a profitable economy should embody and motivate a common force to drive the campaign for a nanotechnology revolution. However, people must be cautioned about the means to a profitable economy. The interdisciplinary nature of nanotechnology should be regarded as the inter-balance and self check-and-

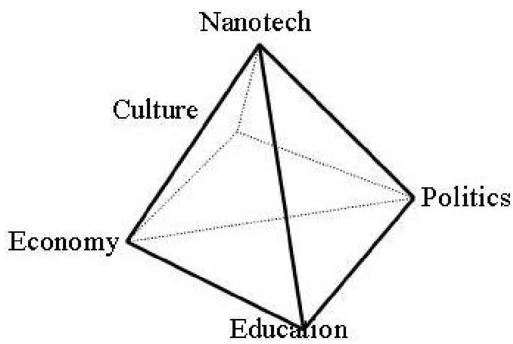

Figure 3: Meta-interactions with society.

control mechanism among those technologies. In other words, the respect of life, nature's metabolism, the diversity of cultures and the sustainability of the eco-system should be the priorities of the ideology for nanotechnology.

Before leaving this section, Table 1 is presented in which meta-physical courses are among the nanotechnology interdisciplinary curriculum, and the course of culture and technology is recommended in a previous paper [16].

The term *culture* has been used by different persons for different meanings, and also has been transformed with time and with the history of human progress, especially with the technological evolution of the past century. Capra defines culture as *a distinctive way of life of a people or social group, and also dynamically as an active cultivation of human mind* [17]. In this article, the author is particularly concerned with the impact of technologies upon culture, or vice versa. With the increasing pace of technological changes in recent decades, the intensity of interactions and the rate of cultural formation or transformation have increased significantly. The rise of new information technology, along with dynamic media forces, is anticipated to intensify the interactions between nanotechnology and culture. The realisation of such active interactions is essential to enlighten people to formulate the ideology of nanotechnology.

The meta-interactions between technology and culture have been an intriguing topic, particularly in recent years. A culture is usually created and sustained by a network of communications, in which a common meaning or consensus is generated. Such a meaning or consensus is gradually embodied into artefacts, written texts, arts and architectures, etc, through which the meaning of culture is passed on from one generation to another. With the increasing pace of technological changes in recent decades, the intensity of interactions and rate of cultural formation have increased significantly. The rise of new information technology – along with dynamic media forces – is anticipated to intensify the interactions between nano-technology and culture.

Course Category	Course Names
Basic courses	1. General Intro: state of the art 2. Nanoelectronic fundamental 3. Nanomaterials and chemistry
Advanced and practical courses	4. Intro quantum physics/ chemistry 5. Biosphere and ecosystem 6. Bio/Molecular electronics 7. Nanofabrication materials/ processes 8. Single electron devices
Hands-on lab/projects	9. DNA structure and computing 10. Nano-characterisation (lab) 11. Nano-devices hands-on test (lab)
Meta-physical courses	12. Culture and technology 13. Ethics and intellectual property

Table 1: Nanotechnology interdisciplinary curriculum.

THE INTELLECT OF NANOTECHNOLOGY

The intellect should include at least the educators, scientists, engineers and media science-tech advocators. Since nanotechnology is still in its infant stage, its technological definition is still ambiguous. Multiple disciplines are involved, fully-fledged intellect is still meagre, and the educational and training structure is still feeble. It is time for engineering educators to get together to design and advocate guidelines and a structural framework for schools and industries to follow before too many self-claimed teaching/training programmes pop up here and there, misleading the efforts to build up a high quality workforce.

The curiously fast growth of nano-related Internet names is one example what is happening to nanotechnology. A US businessperson, S. Sobol, has pre-registered more than 900 nano-prefixed Internet names. Some are quite creative, such as: nanorobotics.com, nanocolor.com and even nanosociology.com [18]. Nanotechnology has become intellectual property without substance or mature product. The same may happen to nanotechnology in the educational domain. Departments may dub themselves *nanotechnology* without realising the full scope and depth of what their programmes should provide.

A recent *Silicon Valley Economic Future Forum*, sponsored by the *San Jose Mercury News*, provides a good model for building up the intellect of nanotechnology effectively [19]. The panel consisted of two university educators, an industrial designer, a government researcher and a state senator. The consensus of the panellists seemed to focus on three points, namely:

- The key factor that will drive competition is *education, education, education*;
- The new model for creating opportunities in today's competitive world is to bring a diversity of people (talents) together as a team to bring forth creativity and new solutions;
- The quality of the workforce and the cultural elements of society determine the sustainability of a newborn technology.

So, education, a diversity of talents and social culture are the driving forces for creating and preserving the quality workforce of intellect for nanotechnology.

The Silicon Valley of the Bay Area is at the crossroads of technological transition. The Internet bubble of the late 1990s and the 9/11 shockwave of 2001 scared away some 200,000 jobs. Yet basically the core of intellect still resides in the Bay Area along with excellent educational institutions like Stanford, UC-San Francisco, UC-Berkeley, UC-Santa Clara, etc.

The emerging growth of biotechnology practices and the new impetus of nanotechnology, combined with some other high-end, computer information oriented technologies, may soon bring the tottering Silicon Valley back to its own feet to move forward with a new workforce of intellect that is tuned in to nanotechnology.

A similar analogy may be applied to the Silicon Valley of Taiwan in Hsinchu, where semiconductor fabs and electronic devices and packaging have been a *thumbs-up* success and issue of pride for the past two decades. However, the gloss seems to be fading because of the ever-increasing exodus of industry, workforce, investment and technology across the strait to China in recent years. Hsinchu is facing a similar challenge of technological transition as the Bay Area's Silicon Valley. China is like a huge magnet continuously pulling away Hsinchu's technological advantages and resources.

Taiwan must seriously find a new direction of transition for the future of its Silicon Valley before it is drained out of its workforce and momentum of intellect. The author suggests that Hsinchu may again follow the footsteps of the Bay Area's Silicon Valley by focusing on *semiconductor-nanotechnology*, which is only one area of nanotechnology, but it is a promising strategy for Hsinchu's future. Such a transition will still give Taiwan the technological edge with its accumulated resources of the semiconductor industry, allowing Taiwan to gradually enter the nanotechnology mainstream.

INTEGRATED AND INNOVATED CURRICULA FOR NANOTECHNOLOGY

The need for the restructuring, connection and integration of engineering curricula to meet the increasing challenges of interdisciplinary research and education has been well recognised and discussed among the educational and industrial communities for some time. In the USA, the National Science Foundation (NSF) has initiated the issue and led such discussions since the mid-1980s [20]. Drexel University has been a strong proponent for curricula changes and initiated the *Drexel E4 Project* in the early 1990s [21-23].

While the Drexel Project takes the entire School of Engineering into consideration for curriculum integration, some universities and institutions lean towards modelling of studies for integrated curriculum development of smaller groups in engineering schools. In recent years, several interesting models for such studies have been developed. For example, a naturalistic model was proposed in the early 1970s [24]. Further, there are models borrowed from ant colonies [25][26]. More recently, many models were derived from neurological or human brain studies [27-29].

Based on some reports published in 2003, only a few universities offer undergraduate degrees in nanotechnology (eg only the University of Pennsylvania, Dakota Technical College, and the University of Minnesota), but quite a few offer MS degrees (eg Rice University, the University of Albany, Rensselaer Polytechnic Institute and the University of Washington); a few institutions even offer PhD degrees (eg the University of Albany, the University of Washington, the University of Texas at Austin, and the University of California-Berkeley) [30]. More recent reports indicated that Texas State University at San Marcos, USA, has had a Nanomaterials Applications Centre since 2002, and Carnegie Mellon University announced the establishment of a Centre for Nano-Enabled Devices and Energy Technology [31][32].

PROBLEMS WITH NANOTECHNOLOGY CURRICULUM INTEGRATION

The above projects and studies are for a general and larger scale of curriculum integration across an engineering school's education. They were brought forth a quarter of a century ago and are still in the stage of case studies or projected research and assessment. However, they form a good foundation for an integrated curriculum for nanotechnology and, in their course of their development, have uncovered many hidden problems associated with curriculum changes and integrations. One should carefully review these cases before developing nanotechnology curricula. Any curricula changes and integration, be they large or small in scale, should face and overcome similar problems sooner or later. Some anticipated problems are summarised below.

Faculty Resistance and Rivalry

In general, faculty members who are, or will be, involved in any curriculum changes are subject to the sentiment of stability and the inertia of routines. At least, such inclinations have been observed in Taiwan. The whole society has been addicted to a political slogan of *maintaining the status quo* for several decades in the past. Such a mentality is still deep rooted in many teachers of the K-12 levels, as well as college faculty members. Only a minority of them hold insight and foresight for changes that are geared towards a better future.

Faculty staff often show signs of reluctance, resistance and even rivalry against curriculum changes, should such changes require readjustment in their specialties and teaching methodologies. Some are even worried for the loss of their teaching jobs.

Integration versus Flexibility Argument

Integration tends to rigidly bind together some courses in terms of their continuity, connectivity and progress, which otherwise hardly existed before integration. Most teachers rather enjoyed their freedom of flexibility in course contents and course progress. Even to administrators, the assessment of achievements tends to become complicated and inconclusive for integrated curricula. So, the trade-off between integration and flexibility requires wisdom, strategy and patience.

Evaluation Criteria and Assessment Methodologies

It is recognised that any evaluation and assessment of teaching efficiency involves participation and the opinion reflections of students. Oftentimes, students react emotionally and irrationally towards evaluations or opinion surveys, making an assessment of the progress of any new programme difficult.

However, there is no exception for the evaluation and assessment of progress for the integration of curricula. The retention rates (data) of students have been used quite often, yet these may be more subjective than opinion surveys of the students at school. Such data involves the investigative work beyond students' graduation into their job performance. So, there exist some factors beyond the control of assessors.

Cost of Integration

The integration of curricula require introducing or creating some new courses for the new curricula, which certainly increases costs. Expenses for coordination or administration among courses is inevitable. Costs for evaluation and assessment are always required periodically.

In order to create a new curriculum, some new teaching materials and tools are always called for in order to facilitate good connectivity and to provide new courses and new pedagogies. Such additional costs may decrease over time, but there will be initially some need for substantial initiatives from government or industry.

Industrial Support and Social Consensus

Significant industrial changes with technology transitions are the primary impetus for curriculum changes and integrations. Hence, industry support is important for successful integration. Industry support is manifold and includes the following:

- Preferential job offerings to those students who have participated in integrated curricula should be the most direct and assertive action from industry;
- The sharing of industrial equipment or laboratories for integrated curricula;
- The nanotechnology curriculum especially demands some advanced high-resolution equipment for hands-on courses, which are quite expensive but definitely serve as gateways to impress students with fresh motivation; indeed, it is proposed that a *mobile nanotechnology laboratory* with advanced equipment be provided by government and industry for nanotechnology hands-on courses of integrated curricula.

Similar problems exist between the large-scale integrated curricula of the entire engineering education and the limited-scale integrated curricula of nanotechnology education, but there are also significant differences. The niche of nanotechnology education is its timely convergence of several high technologies that are aimed at a new revolution of nanotechnology, and a profound linkage between the material world and the living world. These inherent characteristics of nanotechnology education have the potential to enable the integration of nanotechnology curriculum to be distinguished from the general and across-the-board engineering education, and to provide powerful strategies and weapons to overcome most of the problems discussed above.

It is time to convince industry and society that a large-scale nanotechnology education is a must for bringing forth a healthy and successful infrastructure for the nanotechnology industry. Such a reformation in education does not start on, and stop at, academic excellence programmes for a few top ranking universities, as was designed by the Taiwanese government. It is proposed that, at minimum, nanotechnology education programmes should encompass mid-level schools to universities, if not quite a *from-cradle-to-grave* scale of education. Interdisciplinary programmes should stress the connection between the material world and the living world. In fact, such a strategy has been partially carried out for a year through the Central Taiwan Nanotechnology Personnel Training Alliance, which is supposed to be under the umbrella of the Frontier Educational Program for Nanotechnology supported by the Taiwanese government [33].

In this article, the author is particularly concerned with the interactions of nanotechnology with education and culture. Education, particularly engineering education, should be a long-term interdisciplinary objective and investment for the development of human resources in nanotechnology. A more detailed exposition of this point, including teaching and training curriculum, can be found in a prior paper by the author [16].

An example of a nanotechnology teaching curriculum is shown in Table 1. There are four categories, namely:

- Basic courses;
- Advanced and practical courses;
- Hands-on laboratory/projects;
- Metaphysical courses.

This has been designed primarily for a graduate curriculum, so advanced and practical courses may be dropped from the undergraduate curriculum. Basic courses are recommended for the high school level.

CONCLUSION

The ideology and strategies for nanotechnology engineering education to meet the challenge of the new nanotechnology revolution of this century have been identified and illuminated in this article. Nanotechnology education is multidisciplinary in its curriculum contents, crosses the boundary of the material and living worlds, provides a new opportunity for entering a science-technology-driven economy, and offers hope for mobilising engineering education out of the declining trend in engineering enrolments and social recognition.

A broader goal of nanotechnology education should be to educate and prepare citizens from all population spectra in order to be part of a high quality workforce be engaged in a science-technology-driven economy. Any nation that fails to take hold of this opportunity will risk falling behind in its competitive edge economically and intellectually.

Instead of digging into the mechanics or the hardware of how to design the courses and the integrated curricula of nanotechnology, which has been discussed previously by the author, this article's focus is upon the ideology or the software of nanotechnology engineering education [16]. The interplay between nanotechnology and biotechnology, materials, and information technology, are the technical driving forces for the nanotechnology revolution, while the meta-interactions with politics, economy, culture and education provide synergistic and non-technical power for the sustainability of the nanotechnology revolution. In this century, engineering education is facing the challenge of, and is also endowed with, the responsibility and opportunity to lead the nanotechnology revolution. It is also an opportunity for the engineering community to build up a workforce of interdisciplinary technologies and to enhance the prestige and confidence of engineers in society.

After all, nanotechnology is simply an art and science of novel applications of nature's order (NANO). However, nature is to be learned, not to be controlled, nor to be modified. Indeed, it is a revolution that brings humans closer to nature and in harmony with their lives.

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BIOGRAPHY

Dr Fong-Ming (Franklin) Lee was a Professor and Dean of the College of Engineering in the Faculty of Materials Science and Manufacturing at the Chinese Culture University in Taipei, Taiwan. He received his BS in mechanical engineering from National Taiwan University and his MS in metallurgical engineering from NC State University. In 1968, he received his PhD in materials science and engineering from Stanford University. He worked in industry for 25 years; first for IBM and then for Litton Industries.

For more than 30 years, he devoted himself to electronic connector and interconnection technology and authored many papers and several patents in this field. In 1993, he founded the Taiwan Electronic Connector Association (TECA), which is now an organisation of more than 80 corporate members. He also served as a Research Member of the Science and Technology Advisory Group under the Executive Yuan of the Government, and as a Consultant Member for the Industrial Technology Research Institute (ITRI).

In recent years, Prof. Lee become engaged in research activities related to nano-structured materials, and conducted an *International Symposium on Nano-Structured and Amorphous Materials* in April 2000. Prof. Lee contributed papers to UICEE-run conferences since 1999, and was also an active member of the UICEE. In 2000, at the *2nd Global Congress on Engineering Education*, Prof. Lee received the prestigious UICEE Silver Badge of Honour for his outstanding contributions to global engineering education and the achievements of the UICEE.

Prof. Lee was the Director of the *Centre for Cultures & Technologies in Asia* (CCTA), a satellite centre of the UICEE based at the Chinese Culture University, which became a Partner institution of the UICEE in November 2002.

Prof. F-M. Lee passed away on 25 September 2005.

Proceedings of the 4th Asia-Pacific Forum on Engineering and Technology Education

edited by Zenon J. Pudlowski

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