A Study on the Indicators of the Nanotechnology Literacy and Ability of the University Students

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Abstract *—Nanotechnology is the new revolution of material after the information technology revolution. It can apply in our daily life widely. The advantages of nanotechnology such as using effectively and environmental protection will play an important role in the future. The components of nanotechnology will be more environmental friendly, energy saving and high efficiency. Combine with other industries will create new industries in 21 Century the same as industrial revolution. Nanotechnology will make the industrial renewing around the world. The most important impact of nanotechnology will be different from the past industrial revolution; it will not be pursuing economic or industry without expenses of environment. Economic growth and environmental protection can take into account at the same time. In the global knowledge-based economical development, the impacts of implementation for nanotechnology are deep and wide especially in competitiveness of industries in any countries. During the time of nano-industry forming, we need to develop nanotechnology literacy as soon as possible; therefore, increasing general public' understandings of nanotechnology can not be ignored in order to promote the nanotechnology industry. Nanotechnology can be divided into seven areas: physics, chemistry, materials, electrons, mechanism, biology and medicine. The institute of National Science and Technology plans to promote in these seven areas, so preparing to implement relevant courses as to conduct research training program are processing. They must have significant impacts on high-tech industry development. In order to enhance national competitiveness, the implementing courses of nano-science technology for colleges must be in a hurry because they are well-educated and the most direct force in society. According to these background and motivation, this paper aims to construct indicators of the ability of nano-science technology, and then to develop general education course for teaching materials. Through literature review, interview, expert seminars to collect the information for analyzed. Based on the findings which been make recommendations to nanotechnology literacy of university students, increasing basic ability of nanotechnology, course planning and implementation, and developing nanotechnology human resources at manufactures.*

Index Terms *—nanotechnology, literacy, ability, university students*

INTRODUCTION

Nano findings were from the "father of nanotechnology" Feynman academician. He predicted the development of human technology would move unheard of in the development of small size (Yang, 2005). With the technology of the Great Leap Forward, in late 1970 AD, United States, Japan, Western Europe and Russia began to devote in study of ultrafine particles, and had observe that some predictable nano-phenomenon in physics and in chemistry were different way from those in the traditional domains. After 1980 AD, slight molecular analytical instruments continued the invention and popularization, provide nano meter scales of observation, analysis, the study of physical and chemical properties, and manipulation tools and ability in atomic / molecular levels (Yearbook of Science and Technology in ROC, 2003).

The potential application nano-technology have included chemical engineering in daily lives, energy and environmental protection, optoelectronics information, military defense, medical biotechnology and other fields. The influencing ranges of nano-technology are deep and wide, as well as they create infinite business opportunities. Moreover, all the advantages of nano-technology both on effective usage and on protecting the environment will play an important role in the future. The manufacture components made of/from nano-technology will be more environmental friendly, power saving and high efficiency than today's bulky components did. Combination of these benefits with other industries will stimulate the developing of new industries in the twenty-first century. The same as the previous tides of industrial revolutions, nano-technology will lead to another wave of industrial rebuild around the world. The most important impact of nanotechnology will be different from the previous industries or the industrial revolutions, because pursuing growth on economy or on industry will not ruin of environment anymore; that is, economic growth and environmental protection can be collateral and without conflict. Anyway, nano-technology is a green industrial revolution (Ma, 2002). In 2006, in

the outcomes representation -'Taiwan delivered the results on ten power electronics research and development by seven technical colleges' in Taiwan, we found that the developments of nanotechnology not only achieved actual market demands, but also reached provincial efforts, such as saving time, saving costs, and achieving optimal efficiency and results outsider, even more emphasized on using recycled resources, reduced waste production and increase reuse of resources. Thus, nanotechnology is a genuine green technology.

All industry in Taiwan is aggressively developing nanotechnology at the present time, and the government is doing its best to promote nanotechnology. For example, the Executive Yuan listed nanotechnology be the main national development plan in 2008, and the government spent 16 billion on establishing 'Nano-Center' in industrial technology research institute and 'Nano Technology Industry Association' to service industry (Pan, 2004). In addition, the National Science Council in Executive Yuan and its' relevant departments worked together to set up 'Nano-National Science and Technology Program' since 2003, a period of six years, for main domestic nanotechnology research center. This program included four sub-projects which were 'Academic Excellence Research Project', 'Industrial Plan', 'Core Facilities Research Program' and 'Talent Fostering Program'. All of the four sub-projects, the "Talent Fostering Program" is the cornerstone for the revitalization of the enlightenment and hope to foster talents in nanotechnology through promoting this program. In the developing context of global economic knowledge, the effect of promoting nano-technology in the industries and competitiveness is a deep and broad in every nation (Li, Wu, Cai, Lin, Huang; 2003).

The implementation on nanotechnology needs overall co-ordination of each organizer. This requires academic institutions in no governmental circles to integrate 'Ministry of Education' and 'Research and Development Units in Nanotechnology'. Therefore, we will not only nurture nanotechnology talent, but also achieve the effect of extended to the industry, make overall promotion of nanotechnology to achieve together both inside and outside. Teaching materials of nano include synthetic of nano-materials, calculations of nano-theoretic, analysis of nano-materials and equipment operations, and mechanisms of nano-way power, etc. The universities will need to establish special program or general educational curriculums to cultivate talent; therefore, if we can construct proficiency indicators of nano-technology literacy, there will be significant meaning and value on the talent fostering in nanotechnology and so forth.

RESEARCH PURPOSES

According to the research background and motivation, the purpose of this study are summarized as follows: (1) to explore the meanings and contents of the nano-technology literacy by literature reviewing both from domestic and from overseas in order to construct the theoretical background in this study; (2) to construct the indicators of undergraduates' ability on nano-technology literacy in Taiwan, (3) to provide some recommendation to foster talents with nano-technology literacy at university and to be references in implementation related curriculum in Taiwan standing on the results from this research.

RESEARCH METHODS

In order to construct the indicators of nanotechnology literacy, this study searched the relevant theoretical literature, collection and then reduction these documents to dimensions of nanotechnology literacy. On the bases of these dimensions, this study frames became the preliminary indicators for nanotechnology literacy of undergraduates in Taiwan. By underpinning literature to construct content validity, and by scholars' and experts' opinions to make expert validity, this study successfully constructed the indicators and established their levels in terms of its importance finally. These indicators with levels will be the references for outlines of general education curriculums on nanotechnology in university consequently.

LITERATURE UNDERPINNING

According to the relevant academic literature, introduction of nanotechnology should include seven items, including the basic concepts of physics and energy, the measurements of physical structure and material, the basic theory of nanotechnology (such as nano size), the rationale of nanotechnology and properties of mechanics, magnetic and the purpose of developing nanotechnology, the development process of human civilization, the current development of nanotechnology industry, the application of nanotechnology in medical, electric power, agriculture, and livelihood products (Chang, 2002; Chang, 2005; Hsu & Wu, 1996; Huang, 2005; Li & Chin, 2009; Lin, 2002; Lin, 2005; Lin & Lin, 2001; Liu, 2001; Wang, 2002; Wang &Wei & Kao, 2001;Wu, 2004; Tsai, 2005; Tsai, 2003; Yang, 2004).

In the relationship between nanotechnology and environment, we summarize the relevant literatures into nine items, including the types of pollutants and the impact on the ecology, the kinds and principles of pollution control technology, risk assessment used in environmental management methods and design, the meaning and concept of environmental

ecology, industrial ecology in the ecological interactive relationships and ecological management technology, sustainable operation in nanotechnology, mechanisms of catalysis, current energy and renewable energy, nano-particles on human health hazards (Chen, 2003; Hsiao, 2008; Hsu, 2009; Juan et al., 2008; Ku, 2008; Lam & Warheit,2004; Lei et al., 2004; Li, 2003; Li, 2009; Li & Hsu,2004; Lin & Hu & Lin,2008; Lu, 2009; Wang, 2007).

In the analysis and measurement of nanotechnology, according to the introduction of Micro-Electro-Mechanical System in Southern Taiwan University of Technology, the important observation instruments in nano-grade should be included Scanning Probe Micro Scope (SPM), Scanning Tunneling Microscope (STM), Atomic Force Microscopy (AFM), Scanning Electron Microscope (SEM), and Transmission Electron Microscope (TEM).

According to relevant literature reports, the concept of nano-materials could be summarized into five items, including the categories of nano-materials (such as nano-carbon tube, nono-powders), characters and applications of nano-materials (such as properties of optics, effects of electric magnetism, and conductivities of heat), technological application of nano-technology, the processing technology of nano-technology (such as technology of LIG, technique of etching), and preparation of nano-materials (Commercial Times,2003; Department of Chemical Engineering, NTHU, 2008; Economic Daily News, 2002; Hu, 2004; IT IS, 2005; Lu, 2003; Nano-science & nanotechnology, 2009; Nsysu Center for Nano-Science, 2009; Ma, 2004; Wu, 2003).

Based on the research of scholars, the concept for nanotechnologies of electronic and optoelectronic devices should include spintroncis, new dielectric materials, single electron transistor (SET), quantum devices and CNT Devices (Chang, 2006; Chang & Luan, 2006; Kuan & Sun, 2002; Li & Lin, 2009; Liu & Yu, 2002; Ma, 2004).

The aspects of indicators on the concept of nano-chemical technology include the relationship between nano-science technology and technology in people's livelihood, the theories of nano-chemical technology, and application of nano-chemical technology in industries, and so on (Chiu, 20028; Epoch times, 2004; Hsu, 2004; Hsu & Chang, 2004; Plastics Industry Development Center, 2009; Science & Technology Policy Research and Information Center, 2009; Yang et al., 2004).

In the concept of nano-food science and technology, the indicators should include three items, theories of nano-food science and technology (such as techniques of nano-biosensor, benefits of nano-food, detectors of genetic engineering), applications of nanotechnology in food areas (such as preserve, maintain fresh, ferment, decompose, etc.) and the current status of nano-food science and technology and future trends (Chen, 2008; Helmut Kaiser, 2004; Lungteng Cultural Co., 2009; National Ilan University Department of Food Science, 2009; 10 wave International Co., 2006).

According to relevant literature of nano-biotechnology, it should include introduction of nano-biotechnology, the application fields of nano-biotechnology, and the current status of nano-biotechnology and future trends (Chiang, 2002; Chen, 2007; Chemnet Co.,2009; Fang, 2008).

According to relevant literature of nanotechnology in medicine and health, the indicators should include introduction of nano-medical technology, the application areas of nano-medical technology (such as the stem cell research), the current status of nano-medical technology, and future trends (Center for Nano-medicine Research, 2008; Taiwan Journal of Public Health, 2006; Taiwan Journal of Public Health，2009; Yang & Lo & Tai, 2009).

RESEARCH FRAMEWORK AND IMPLEMENTATION

1. ***Research framework***

According to the literature reviewing, we design the research framework in this study as below:

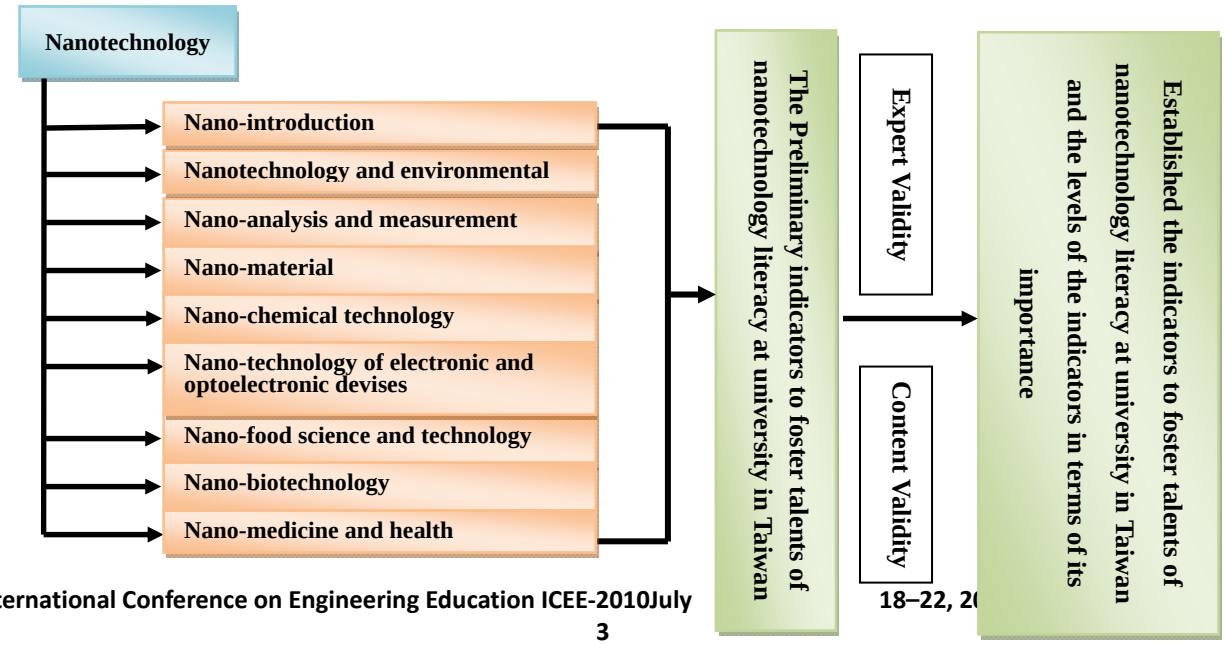

Fig. 1 Research framework in this study

2. Implementation

By analysis research literatures, the preliminary indicators of nanotechnology literacy were established to foster talents of nanotechnology from content validity, and by scholars' and experts' opinions to make expert validity. The scholars and experts were listing in table 1:

Institution	Affiliation	Scholars and Experts
National Chung Hsing University	Dean of Engineering	Fu-Sheng Syue
National Taiwan Normal University	Electrical and Professor and Chairman, Department of Science and Technology	Jin-Bao Chen
Nursing And Management College	Cosmetic Application and Management Professor and Director	Jhin-Ming Ma
Cheng Shiu University	Professor, Institute of Management	Si-Ci Siao
National Taiwan University	Professor of Polymer Science and Engineering Research Institute	Jiang-Jhen lin
National Chung cheng Unversity	Associate Professor of Mechanical Engineering	Yi-Ling Jhang
National Ilan University	Professor, Department of Food Science	Huei-Huang Chen
National Ilan University	Biology Assistant Professor of Electrical Engineering	Yi-Pei Yang
National Ilan University	Professor of Environmental Engineering	Jhang-Tang Jhang
National Ilan University	Department of Chemical and Materials Engineering Professor	Shen-Mao Lai

Table 1 Lists of scholars and experts invited from nano-field in this study

RESEARCH FINDINGS AND DISCUSSIONS

In order to integrate nanotechnology to students' daily life, as well as to inspire their creativity and multiple logical thinking, development indicators in this study can satisfy detecting the ability of students for domestic and foreign academic and industrial needs. The research findings are as the followings:

The literacy of nanotechnology for undergraduates should involve nine dimensions of literacy (41 items). The nine dimensions of literacy are including the introduction of nanotechnology, nanotechnology and environmental problems, analysis and measures of nanotechnology, nano-materials, nano-chemical technology, nanotechnologies of electronic and optoelectronic devices, nano-food science and technology, nano-biotechnology, and nanotechnology in medicine and health.

In regarding to the introduction of nanotechnology, undergraduates should understand basic substance energy concepts such as substance' category and theorem, the structure and material of matter such as atomism theory, the application of microscope and the effects of complex molecules in daily life, nanotechnology concepts such as the definition of nano-scale and characteristics, the purposes of developing nano-technology such as nanotechnology for developing and hazardous to the environment, the relationship of nanotechnology developing history and the daily life such as their correlation between nano-technology and the quality of life, the important application of nanotechnology in optoelectronic devices, production in agriculture, military technology, articles for daily use and so on.

Considering to the concept of nanotechnology and environment, undergraduates should understand the types of pollutants such as the sources and categories of pollutants, environmental pollutants' impacts on ecology and the ways of pollution control, the assessment of risk and management in environment such as assess risks, the design of environmental management system in Taiwan, environmental ecology such as the interaction relationships between industrial materials and ecology, management technology of enterprises and the sustainability management of nanotechnology, mechanisms of nano-catalysts such as the categories of nano-catalysts, and their applications, energy such as the current status of energy in the world, categories of reproducing energies and their applications, health hazards of nano-particles and consideration of choosing nano-products.

Regarding as the observation technology in nano level, undergraduates should understand the overall introduction such as the observational techniques of nano-analysis and their importance n the developing of nanotechnologies, SPM such as the features of SPM and its application to nano-technologies, STM such as the features of STM and its application to nanotechnologies, AFM such as the 3D images of AFM and applying to observe the properties of cells, SEM such as the SEM used electron gun shooting effects on material surface to generate imaging and application to observe materials with non-electron conductivities, and TEM such as the accelerate the electron impact imaging of TEM and applying to observe crystals, chemicals and distribution of electron structures.

In the concept of nano-materials, undergraduates should understand the categories of nano-materials such as the structure of nano-materials, the nature of nano-materials such as the properties of nano-particles, the rigidity and toughness of organic and non-organic nano-materials, the applications of nano-material technology such as the advanced properties of nano-materials, the processing technology of nano-materials such as the processing categories of nano-materials, and the preparation of nano-materials such as preparations of nano thin film and the ways of bulk materials.

For the concept of n nano-chemical, undergraduates should understand nanotechnologies and livelihood chemical engineering such as the properties and applications of nano-fibers, nano-tubes, high speed and high frequencies signals of nano-wires and nano-plastics on catalysis mechanisms in industries, the nano-chemical technologies such as the properties of nano-powders, the size dependences of nano-crystals and thermodynamics, the application fields of nano-chemical such as the properties of nano high molecular composite materials and applying to livelihood industries, textile industry, packaging materials, electronic packaging industry, catalyst, paint and filters.

Regarding to the concept of nanotechnologies of electronic and optoelectronic devices, undergraduates should understand the techniques of nano-electrons such as the characteristics of electronic components, the applications of electronic and optoelectronic devices such as improving the techniques of mico-image and applying to optics, energy and storage, and the development of nanotechnologies of electronic and optoelectronic devices in future trends such as the techniques of electronics beam etching, more smaller, quicker, and cooler.

In the concept of nano-food technology, undergraduates should understand the introduction of nano-food technology such as the benefits of the human body, the chemical pollutions on food and agricultural products and microbial detection, the sign and logos of nano-food technology, the applications of nano-food technology such as food nano grade process technology, applying to food package and nano gold particles, nano fibers, food and nano grade milk and nano grade monitoring system, and the current status and future trends such as certification of U.S. Food and Drug Administration, the potential toxicity of nano-particles, control of nano-food additives, and nano technology development trend of food.

For the concept of nano-biotechnology, undergraduates should understand the introduction of nano-biotechnology such as the nano characteristics of organisms in nature, the application fields of nano-biotechnology such as the benefits of nano-biotechnology in health food, pharmaceuticals, cosmetics, chemical warfare agents and bacteria detection, and nano blood test in biological microarrays for diagnosis disease, and the current status and future trends of nano-biotechnology such as drug efficiency of nano-biotechnology, the powerful effects of military revolution, and nano scale developments in the field of microscope.

Respecting the concept of nanotechnology in medicine and health, undergraduates should understand the introduction of biomedical applications, the application categories in biomedicine such as the efficiency and effectiveness of nanotechnology in medicine, health and applications in cancer and stem cell research, and the current status and future trends of nanotechnology in medicine and health such as ultra-thin medical patch can void suture and healing and nano medical machinery can reach the nucleus' repairs.

To sum up, this research constructed indicators of the ability of nano-science technology as used to develop general education course syllabus for teaching materials by ways of literature review, interviews, and experts' seminars to collect

the information for analyzed. Based on these findings, they became recommendation to nurture nanotechnology literacy in Taiwan, course planning, and implementing and developing nanotechnology human resources in industries as well.

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