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Research on Creativity Education Incorporating Systems Engineering—An Example with "Intelligent Taiwan"

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Abstract. Upon the arrival of the era of science and technology and information, pluralism and diversification become important trend of industrial development. Facing the rapid industrial revolution and information explosion, human being's creativity has attracted attention; a lot of studies have been done on creativity, resulting in many theories, which have been applied in various areas in recent years.

This research focuses on Taiwan's current technology policy, known as "Intelligent Taiwan", and discusses the possible future Intelligence systems and issues related to continuous development of humanism. We also propose a Three-Dimensional systems engineering framework (5-layer extendable mode), which is adaptable to the future blue print and full of creativity. According to the introduction of the multi-layer value of human, nature, and esthetics, which is developed as the structure of the proposed Three-Dimensional framework, we further discuss the different value perspectives, life-style, and future influence, of systems engineering thinking. In addition, in this paper we also recommend a new thinking of the systems engineering education to link the creativity education. Hence we can expect that the talents trained in the educational way would develop more mew methods, new conceptions, and new theories in the intelligent systems. In this case, our society can become more wholesome, have more excellent engineering creativities, develop continuous new innovations, and finally achieve the intelligent life – Sustainable Humanity and Nature Symbiosis.

Keywords: *Systems Thinking, Creativity, Innovation Industry, Humanity Care, Sustainability and Symbiosis.*

Introduction

With the development of high-tech, the globalization competition is fast changing now, and surging in the knowledge-based economy era. Facing such a wave of new knowledge-based evolution, innovation and its application is the critical ring in the social development chain. Creativity is highly advocated by entrepreneur from various industries and experts from academia. Experts with different background focus their research on both individual creativity and team co-creativity, which is also continuously emphasised by enterprises. The talent required by the future Taiwan development is looming with the promotion of “Intelligent Taiwan” policy. Such talents equipped with diversified background also shoulder the social obligation of leading Taiwan towards science and technology integrated development and environmental protection road.

Creativity is generated under various conditions and under the inter-action of different factors. When advocating creativity, another important issue which should be always kept in mind is that systems thinking must be equipped in the creativity team and in the teamwork allocation. When facing the complex social systems nowadays, the application of systems thinking can help understand the multi-layer of systems engineering and management, and generate original and creative conceptions and ideas from an open and soft-system perspective according to the human and nature evolution background. In addition, in order to promote social progress and harmony, it should not be underestimated to put forth available innovation schemes or to realize the creative ideas by effectively and flexibly employing all the technology resources.

The Fundamental of Creativity

There isn’t a definite definition of *Creativity,* because the definition of any conceptions is based on its theory fundamental. Once the fundamental was evolved or changed, the definition was changed accordingly (Jan, 2002) .

Creativity is the knowledge base of Innovation. Innovation is the practical application of Creativity. The generation of creative idea depends on the extent of exerting the creativity intelligence. And the performance of creative idea is based on the present of innovation achievement (Ministry of Education (Taiwan), 2002).

Through the recent years’ research on creativity from any angle, it is known that creativity is based

on a comprehensive theory, and is pluralistic rather than unitary. Sometimes creativity is a revealing of rationality, and sometimes irrationality. Not only does it require intelligence, as well as sense, cognition, imagination, convergence, and the ability of symbolization and conceptualization, but also environment and individual personalities suited for creativity. Hence, creativity is a unique ability, as well as an integrated ability (Lung-An Chen, 2002).

Therefore the definition of creativity depends on the realm to apply the creativity, because creativity factors required by different specific realms are different. But there is one thing in common in different realms concerning creativity – the unique and non-traditional problem solving ability.

Rhodes (1961) defined Creativity based on 4P – Person, Product, Process, and Place or Press. He described the creativity as an integration of 4P – characteristics of the creative person, stages of thinking used in the creative process, outcomes of creative products, and interaction between creative person and creative press (or environment). Psychologist also gradually noticed that it is insufficient and deficient to explain the creativity as individual action. Hence the study on creativity also progressively shifted from that esteeming the creativity as an individual work to integrated work that required the link between individual and whole system. Creative Problem Solving (CPS) (Osborn, 1953; Parnes, 1967) emphasized the problem solving process in a creative thinking mode, consisting of:

1. Stages – Objective Finding, Fact Finding, Problem Finding, Idea Finding, Solution Finding, and Acceptance-finding.
2. Methods – Divergent Thinking and Convergent Thinking.
3. Outcomes – Review and Action.

Creativity and Its Application to Organization

Sternberg (1988) studied the nature of creativity based on individual creativity and advocated the creativity investment theory. From his research, he esteemed creativity as a confluence of six individual resources: intellectual abilities, knowledge, styles of thinking, personality, motivation and environment. Sternberg & Lubart(1995) proposed that the abilities required by creativity including Synthetic ability (eg. combination, conclusion, trimming, design, synthesis, etc.), Analytic ability (eg. comparison, enumeration, sorting, etc.), and Practical ability (eg. operation,

application, discovering, revision, etc). Only the balanced development and skill cooperation between the three abilities can inspire the creative operation.

Amabile (1996) developed the Componential model in the Creativity Context. He pointed that the generation of a creative product must at least depend on 4 basic elements:

1. Domain-relevant skills: all the competencies and technical skills that are required to succeed in an individual's domain of interest, which lay the fundamental of creativity and benefit for the creativity preparation stage.
2. Creativity-relevant skills: the methods, strategies, and creativity program scheming skills, to inspire, realize, and generate creative ideas. Such skills are related to the reflection ability and quality corresponding to the information or stimulation.
3. Task motivation: the motivation to attract or stimulate individuals to combine abovementioned skills to realize creative products, which exerts influence on the support drive of generating creative ideas.
4. Social environment: an evaluation standards consisting of social values, aesthetics, and other measurements, to assess the value of the creative product. It requires the examination and filtration by social environment to judge whether the creative idea is innovative, pertinent, practical, justified, and valuable.

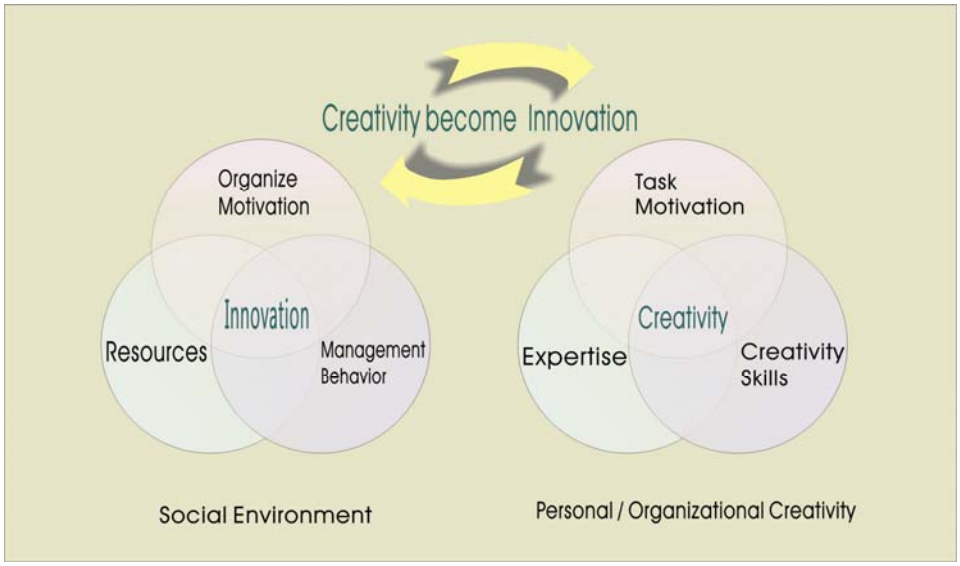

Figure 1. Amabile's Componential Model of Creativity (Resources: Amabile, 1997)

Figure 1 illustrates the four basic elements (Domain-relevant skills, Creativity-relevant skills, Task motivation, and Social environment) and their interactions in Amabile's Componential model of creativity.

Creativity and Systems Thinking

The framework of creativity training stems from creativity training (Lung-An Chen, 2002). In his study, the cognitive element is characterized with divergent and unrelated thinking. Cognitive training includes five important parts: sensitivity, fluency, flexibility, originality, and elaboration. Innovation and Creativity are both related to change and value judgement. And creative ability depends on competencies, motivation, and behaviour. Different person with different background build different tracks in developing their creative ability. And they would also face their own creative summit period in their domain of interest. Each education stage during their creativity training period lays a substantial fundamental for their next stage.

As shown in Table 1, the behaviours of creative ability have something in common with that in scheming systems. Specifically, the creative ability is presented in a segmental way, while in the systems engineering, the behaviours show highly integrated in a thinking mode. Hence we can make sure that when completing the stage of basic divergent creative ability training, systems thinking should be applied. We must understand that as the layer of the creative ability reaches higher, it requires broader abilities in the systems engineering realm. Creative ability becomes an applicable technology instead of a segmental behaviour. It enables us to comprehensively think in a top-down manner, and to envisage the future based on the past experiences. In such a way, creativity paves a fundamental for science and technology advance.

Sensitivity is the ability to detect and reveal problem, as well as the sensitivity towards individual, objects, and environment (Lung-An Chen, 1988, 1993; Sternberg, 1989). Certain people are more sensitive; they can easily sense the unusual or always neglected things. Actually, it is the same to reveal the nature of the problem as to understand the issues, which is also the most important front-end step to address the problem.

Fluency is the ability to come up with various possibilities or solutions of the core systems, to generate certain amount of ideas, as well as the ability to think out as more as possible conceptions and answers (Lung-An Chen, 1988, 1993; Sternberg, 1989). It is a process related to memory

because people store the resources in their mind and then evoke them for certain purpose. People who have the ability to think up multiple solutions in limited time are esteemed to have sufficient fluent thinking ability. It is a presence of delicate reflection and fluent thinking in the training, as well as the ability to identify the whole core systems.

Table 1: Behavior of cognitive ability and its relationship with that in scheming systems

Cognitive Ability	Behaviors	Behaviors in scheming systems (highest layer)
Sensitivity	The ability to reveal the critical issue of a problem	Understand the issues
Fluency	The ability to come up with various solutions to address the problem	Conduct demand analysis and set up required solutions and core capacity.
Flexibility	The ability to go beyond the thinking limitation	Pluralistic thinking to construct core systems and operation procedures.
Originality	The ability to reflect uniquely and innovatively	Balance performance and net contribution
Elaboration	The ability to add in certain new details and to construct related conception clusters	Evaluate the potential preferred solution

Flexibility is the ability to shift thinking mode, expand thinking range, and go beyond thinking limitation (Lung-An Chen, 1988, 1993; Sternberg, 1989). Most people are prone to keep thinking modes catered for their own habits. But some people have the ability to automatically expand their way of thinking to new realm or shift to a pluralistic way. Flexibility enables to pluralistically develop core systems and operation procedures.

Originality is the ability to reflect uniquely. People equipped with this ability can think up new conceptions that others couldn't. The less alike to others' conceptions, the higher originality the person have (Lung-An Chen, 1988, 1993; Sternberg, 1989). Originality is also the ability to generate smart, unusual, unique, and innovative reflection. The reflection should be scarce and fancy, while acceptable; in other words, originality is just like creative performance (efficiency) of core systems in the whole systems. Such efficiency contributes to balanced performance and

value-added.

Elaboration is the ability to plan detailedly, to constantly refine, and to pursue good-to-great. It is also a complementary ability, which is to add new conceptions or new ideas into previous conceptions or basic notions, so as to add in certain new detains and to construct related conception clusters (Lung-An Chen, 1988, 1993; Sternberg, 1989). From a pluralistic thinking perspective, elaboration requires the ability to construct core systems (modularization) and to evaluate the potential preferred solution.

In sum, as to the fundamental of creative ability, we can easily identify that the ultimate objective of creativity training should focus on nurturing talents who have humanitarian quality and nature conscious, which is consistent with the core objective of systems thinking. Looking through top-and-down, mastering the correct direction and understanding the bottom requirement could is conductive to comprehend the environment of issues and related problems. Then it is critical for systems thinking through 'scheming systems' to provide continuous thinking. Future industries should also pay more attention to environment protection and humanitarian share, in order to achieve sustainable development and to build more wholesome society when enterprises fight their way to be more creative to contribute value and to survive.

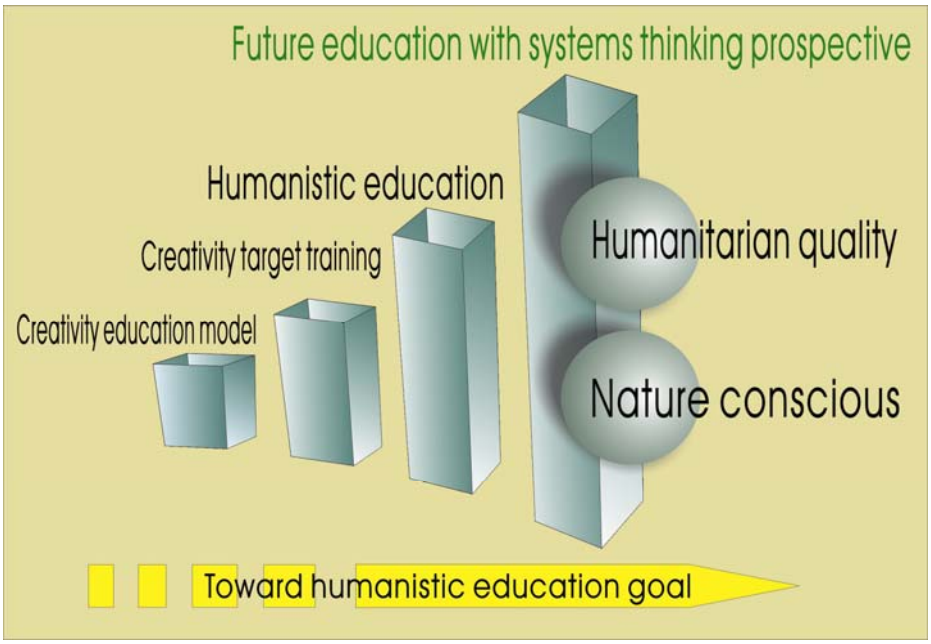

Figure 2. Human-based and nature conscious future education

When the creativity target education is still dedicated to human-based thinking and being nature conscious, the objective to expand future horizon and to carve out quality life through linkage with past experienced thinking is common in nature with systems thinking from a big picture's view. Systems thinking are more meticulous and effective ways to effectually identify and describe complex operation systems in a life-style perspective. It is not a simple consideration in mind, but an effective elaboration in order to make people understand and to share with ones' own thinking. Hence we can safely point out that the next stage after finishing creativity target education is to develop systems thinking to deliver more correct and systemized judgements.

Creativity engineering education in the future must be open education in the systems engineering analysis manner, so as to achieve sustainable development and to build an environment where nature and systems can be inter-compatible. We should develop pluralistic talent education and promote science and technology advance through integrating technologies from mechanics, mathematics, information and communication, engineering, biology, and other sciences, and implementing quality life environment.

Sustainable Humanity and Nature Symbiosis

Product development depends on the systemized integration among science and technology from different realms, vested people, and related databases. Systems development is also related to society, personal psychology and behaviour, cognition and manageability, and even related to culture and politics factors. Knowledge network, technology integration, and industry innovation, can benefit the industry value as a whole to be enhanced through closely linking interested parties to help extend industry value chain; can promote cross-realm knowledge creation and inter-industry integration, and stimulate new opportunities in industry innovation; can contribute to build a cross-institution united promotion platform to boost education and growth, and energy upgrading.

As a matter of fact, the principles of systems thinking have inseparable relationship with creative ability. The one who has excellent creative ability is not necessary to effective shed its creativity in its organization. If we focus the education development in the systems thinking in scheming systems, we certainly will understand the multi-facet of 'Systemized Thinking', and propose original and creative conceptions (ideas) from 'Open and Soft Systems' perspective according to human-nature evolution history. It is impossible to come up with effective creativity to cope with

nowadays complex systems simply by creativities without framework limitation or by fantastic innovations. Only through deploying all technology resources, especially teamwork efforts, can we put forth feasible innovation program. Personal creativity and team creativity both lay a substantial fundamental for organization creativity. Especially the systems thinking when scheming systems is an indispensable ability in creativity. Personal creativity must be cultured by creativity target education, while how to effective apply the creative ability to various practical engineering technologies requires the systems thinking framework. Hence how to continue creativity education in enterprise when individual finishes its creativity training in educational environment should under carefully sustainable research and development through meticulous systems thinking education.

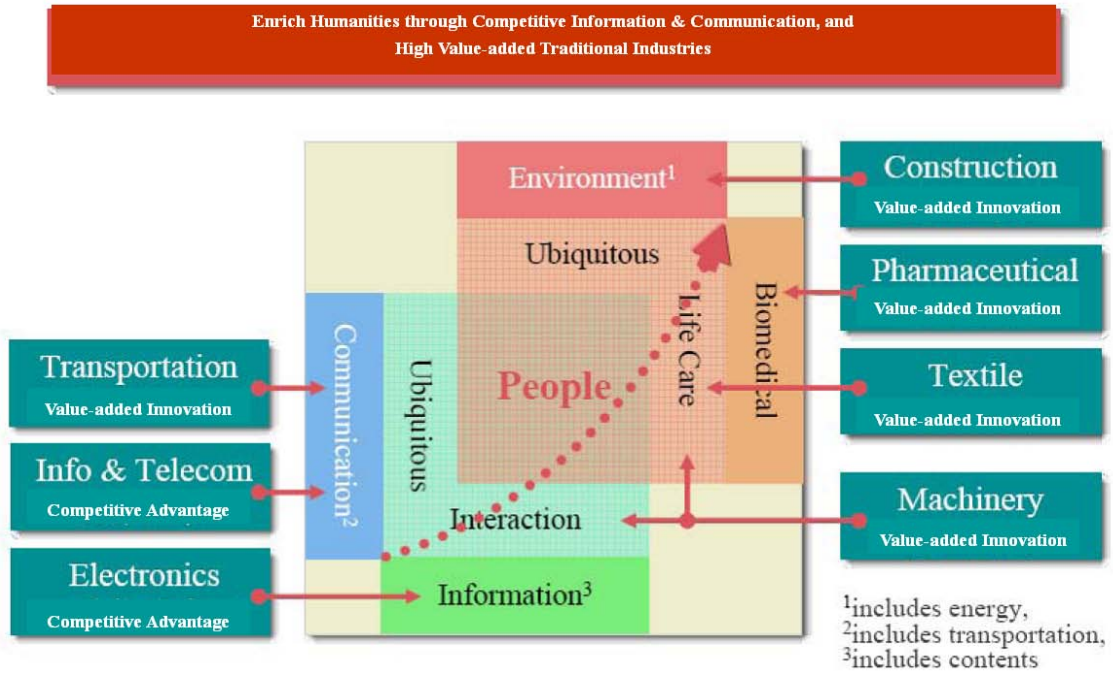

Figure 3. Applying Competitive Information & Communication to Build Human-based industry (Pei-Zen Chang and Mei-Fang Sun)

Recently, strategic development direction of emerging technologies is focused on 'Innovation Foreseeing' and 'Humanistic Research and Development' (as shown in Figure 3), which will also be paid special attentions in advanced life technology development in the following two decades. When it comes to humanistic research & development, we will surely encounter the energy crisis

and environment problems. Therefore, during our way to construct sound science and technology kingdom, environment protection should not be ignored.

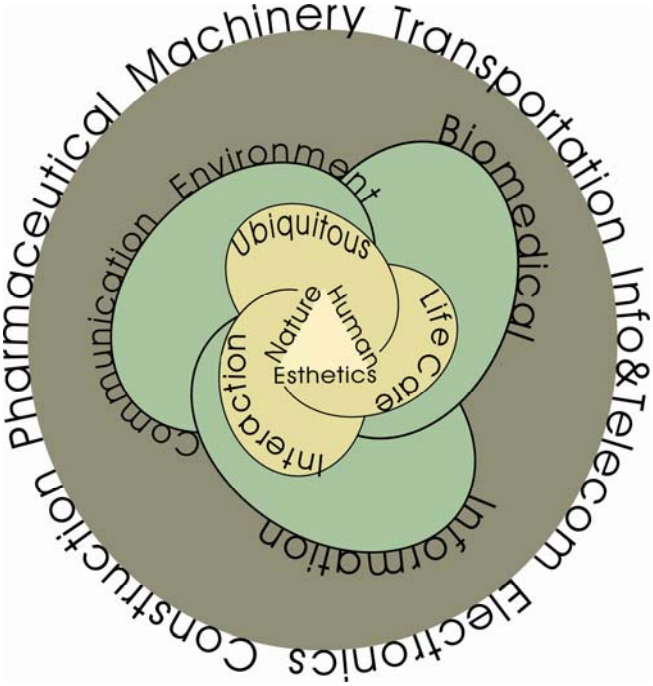

Figure 4 Multi-value Blossom Consisting of Human, Nature, and Esthetics

In the future, revolutionary technology will be further guided by the policy of humanistic Sustainable Living (Evolving) and Human-nature Win-win Development. When advocating Competitive Information & Communication, we should keep in mind that the core value is Human, Nature, and Esthetics (as shown in Figure 4): the triangle core of human-nature-esthetics develops multi-layer environments and products, which are independent and interwoven to each other, just like a bud that progressively grows as a flower with many leaves. In order to nurture the beautiful human-nature-esthetics bud, we should effectively educate pluralistic and compounded systems engineering talents to adapt to the future science and technology development. Creativity is generated through the interaction among people, product, and environment, each of which is indispensable to realize creativity. The Human, Nature, and Esthetics policy must be carried out by human to imitate nature and to enrich esthetics, and finally to form sustainable development core value. In other words, talents education should be paid more attention to by present society, government, and enterprise. Only through exerting combined efforts from all interested parties can we build a more wholesome life environment with more excellent engineering creativity and

continuously social development.

"Intelligent Taiwan"

"Intelligent Taiwan" is one of I-Taiwan twelve infrastructure projects, the content of which including manpower cultivation, cultural and creative industries, building Taiwan into the world's number one wireless broadband country, and constructing intelligent transportation system and intelligent living conditions. Facing the fast changing era, taking advantage of the advance of science and technology to lead the development of industry and society, to improve the citizens' welfare, is the major task of government in the future. Therefore, four topics, including cultural and creative society, intelligent environment, high quality life, and multiple-dimensional talents, are determined, from which, through the coordinating effort and experience from fourteen ministries of the government, ten sub-topics are drafted to demonstrate the government future strategy and direction. It is expected that, the blueprint of I-Taiwan can drive the government to promote critical projects and strategy to benefit the whole society with the advanced science and technology.

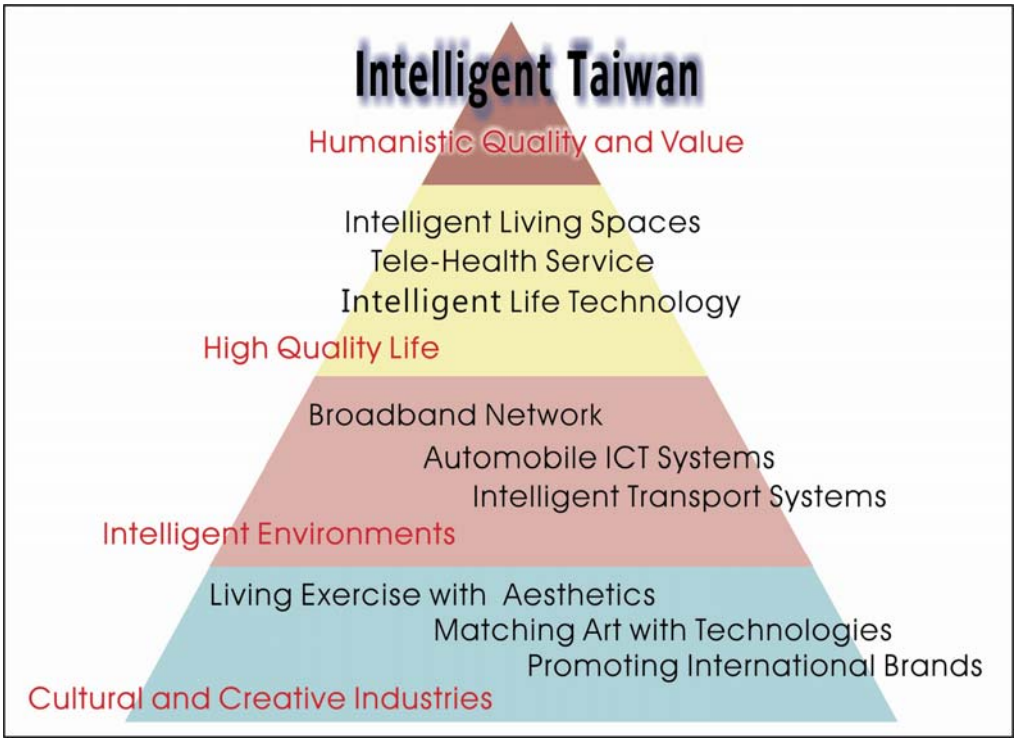

Figure 5. Three Major Tasks of "Intelligent Taiwan"

It is proposed that there are three major tasks to achieve “Intelligent Taiwan”, as shown in Figure 5.

1. Cultural and creative society. That is, to promote new life esthetic campaign, media technology and arts, and world brand cultural and creative industries to change people’s living attitude, and to further influence people into life of better taste.
2. Intelligent environment. Through constructing intelligent transportation system, telematics industrial chain, and broadband superhighway, people can enjoy reliable and fast-popularized access to wireless internet facilities and value-added transportation services.
3. High quality life. By intelligentizing living environment, distance medical care, and applying intelligent life techonology, people can enjoy intelligent living space; and the elderly population can have appropriate health care, so that the advanced technology can enable the benefit of high quality life in our country.

By promoting O2 Service concept (On-Demand, Open Network Service), we can construct intelligent living condition, lead the development of corresponding industries and their integration with intelligent hardware facilities, and improve the quality of people’s life by providing diversified services.

To promote the integration of technology industry in various areas, the problem that we need to take into consideration includes not only the integration of old technology but also the cross-disciplinary research, not only division but also cooperation and interaction of researchers. Detailed market evaluation is required to reduce the high risk of creativity; the language barriers in different areas should also be broken through to reduce the industrial cultural difference of cross-disciplinary integration. Government should also draft new regulations and laws to promote high-technology industry. In response to social change, humanity care related technology should be developed to emphasize the integration of humanism and technology. It is also proposed that we should develop research and education plan similar to future education plan in UK, which promotes fundamental research of human essence and value as the basis to develop technology, and advocates humanism as the starting point of thinking----the purpose of developing technology is for human beings; developing technology should also center on human. How to improve the thinking ability of people on the self worth, enrich people’s mind has become a major issue.

Due to the complexity of the systematic problem, Hitchins proposes 5-layer model, starting from the lowest layer of product, growing to system (project) layer, to business (industrial and systems engineering) layer, to wholesome industry (supply chain systems engineering) layer, and eventually to society and economy (social and economic systems engineering) layer. Applying the above-mentioned 5 layers, it is easy to show graphically the interested system. In 2002, Kasser and Massie add a system life dimension (life cycle) or the second axis, so that it is easier to introduce system and its operation in the life cycle.

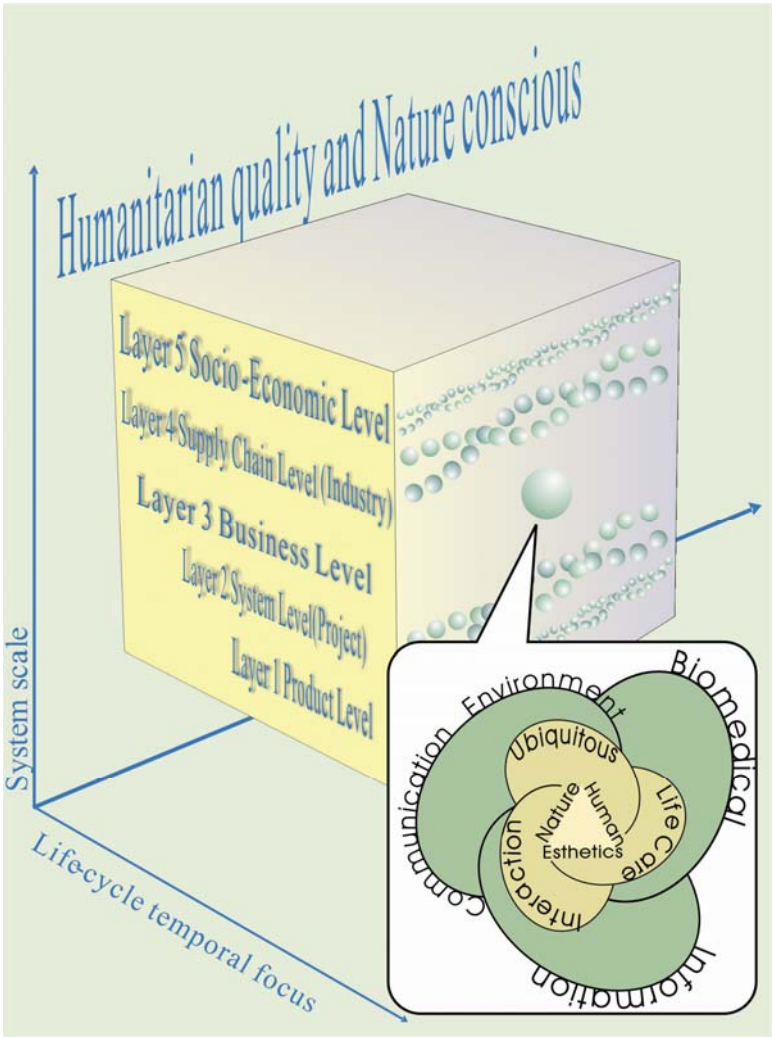

Figure 6. Extendable 5-layer mode

The development of human beings intelligent systems should be closely combined with nature. When developing of creating new intelligent systems, in the meantime of discussing the human nature and esthetics value, we cannot ignore nature. Only if we follow the laws of nature and

coexist with bio-environment, human beings can have continuous development. We understand that all systems (product or service) have different levels of complexity and life cycles. To create an intelligent system with the benefit of co-evolution of continuous life, esthetics and nature, in this paper we suggest a framework of human, nature, and esthetics multi-layer value as the third dimention (third axis), to represent the interaction of all system layers and all system life cycles. Therefore, we discuss how to create human and nature centered extending value, as shown in Figure 6 extendable 5-layer mode, and to further discuss systems engineering thinking of multi-dimensional value, life cycle, and its future impact. In each activity and life cycle, the value created should be constructed gradually by more and more infinite extending single events. It is analogous to the natural development and evolution of human beings gene to construct complex but codependent system.

As shown in the above-mentioned 5-layer mode, this paper suggests systems engineering to educate a new thinking way to incorporate creativity education, so that we can use it to cultivate more and more talents, to propose more and more new methods and concepts of intelligent systems in the future. It is expected that we have better living environment and more outstanding creativity in the future so that we can achieve the intelligent life of sustainable humanity and nature symbiosis.

It can be seen from the above-mentioned new policy and strategy of “Intelligent Taiwan” that systematic thinking has been applied as main concept, and the core value of Human, Nature, Esthetics is leading “Intelligent Taiwan”. The transformation of intelligent life and industries can refer to extendable 5-layer model. In this paper, we suggest to take three steps, systematic thinking, creativity, and systematic thinking and creativity. In such a huge national plan, we need to start from the high level to prioritize the policy, allocate the resource and sort out repeated and unnecessary information, and so on. We should emphasize the frontier complete systematic plan, understand and adopt creativity techniques, reach common consensus on creativity, institute new policies and tasks, and integrate and execute them in systems engineering way.

Conclusion

The promotion of “Intelligent Taiwan” indicate the talents needed in the future, the talents who shoulder the responsibility of leading the country to head to integration of development of science and technology and environment protection. In the future, in the frontline of facing the global

competition, “Intelligent Taiwan” requires inter-disciplinary talents with creativity. Therefore, it is important to adjust the education system to accommodate the global competition, and strengthen students’ humanism and nature care using humanism education, and to connect with past experience, to explore the future, and to pursue continuously the excel of the country and self improvement.

The factors of cognition and non-cognition cannot live independently to generate the solution of creativity; the concept of integration (top-down) is required. When handling complex systems, it is even more important to start from high level, deploy the function, analyze the requirements, and integrate all system levels to make sure the whole system operates and develops well. Therefore, when promoting creativity education and government policies, we have already seen the objective of human centered thinking; what we lack is the educational talents with systems engineering thinking, who can promote the close integration of education and policy in the future.

New concept, new rationale, new methodology, can be only realized by systematic thinking. To establish environment of humanism and sustainable development, we should integrate systems engineering to proactively develop the prospective education and research plan, and eventually achieve the goal of symbiosis and sustainable development of engineering, human, and nature.

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Biography

Willy Y.S. Peng, professor and Vice President of Overseas Chinese Institute of Technology in Taiwan, received his Ph.D degree in Aerospace Engineering from the University of Arizona in January, 1974.He specializes in systems engineering and management, aerospace industry development, large system integration, airframe development, production, logistics, project planning, entrepreneur management and re-restructure. He has been honor consultants in several companies, and listed into Excellent professionals in International Who’s Who of Professional in 1999 version. Prior to joining the academia, he worked in Taiwan aerospace industry for more than 30 years and participated in two large scale systems engineering development projects from commencement to operation with internationally recognized contributions.

Victoria Hsu is now pursuing her master degree in Department of Information Technology, Overseas Chinese Institute of Technology in Taiwan.

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