ITC-CSCC 2013 (The 28th International Technical Conference on Circuits/Systems, Computers and Communications), June 30 – July 3, at The Ocean Resort, Yeosu, Korea

New Waves of Engineering Education and IEA's Graduate Attributes

Plenary: Monday 10:50 – 11:20, on July 1

Room: Grand Ball Room A

Shoji Shinoda

Dr. of Engineering

Waseda University's Invited Researcher, Tokyo

Professor Emeritus of Chuo University, Tokyo

IEEE Life Fellow, IEICE Fellow/Honorary Member, JSST Fellow, and IEEK Member

1. The Queen Elizabeth Prize for Engineering

★ ***The Queen Elizabeth Prize for Engineering is a new global biannual engineering prize of £1 million that rewards and celebrates an individual (or team of up to three people) of any nationality, directly responsible for advancing the positive application of engineering knowledge to a ground-breaking innovation in engineering which has been of global benefit to humanity.***

This prize was created, November 2011, in the United Kingdom with the history of the so-called Industrial Revolution – the transition from the hand production to new manufacturing processes – which began in the period from about 1760 to some time between 1820 and 1840 and had spread to Western Europe and the United States of America.

★ ***The news about the first winners of the prize was announced on March 18,2013.***

★ ***The first winners of the prize were the five outstanding engineers***

Robert Kahn, Vinton Cerf and Louis Pouzin,
Tim Berners-Lee, and
Marc Andreessen

who created the Internet, the World Wide Web, and the Mosaic web browser that initiated a communications revolution which has changed the world.

They received their award from Her Majesty The Queen in front of an audience at the formal prize ceremony, held at the Buckingham Palace in London on June 25, 2013.
Also, each of the winners received a special trophy for the Queen Elizabeth Prize for Engineering.

★ ***Lord Broers, Chair of the Judging Panel for the Prize, says " We had originally planned to award this prize to a team of up to three people. It became apparent during our deliberations that we would have to exceed this time for such an exceptional group of engineers."***

(www.qeprize.org)

★ ***The Queen Elizabeth Prize for Engineering* will inspire a next generation of engineers that take up the challenges of the future.**

★ ***By this prize news, many better and brighter young students with passion, curiosity, engagement and dreams may be attracted and moved than ever to become a next generation of ambitious engineers with creative, innovative and/or entrepreneurial minds.***

★ ***This is also a big chance for HEIs (Higher Education Institutions; universities, institutes, or colleges of 4 years) to reinvent engineering education, by thinking out of the box, in order to attract and get as many of such students as possible.***

2. What are the origins of engineer and engineering?

What are the present meanings of engineer and engineering?

Origins of the words of engine, engineer and engineering

Latin ***ingenium*** ***means*** ***"nature";***
(disposition) bent, character;
(intellect) ability, talent, genius;
(person) genius.

Latin ***ingeniosus*** ***means***
(person) very clever and skillful,
(thing) cleverly made or planned and involving new ideas and methods .

Latin ***ingeniare*** ***means***
contrive [1. invent and/or make a device or other object in a clever and possibly unusual way. 2. to arrange a situation or event, or arrange for something to happen, using clever planning], or
devise [invent a plan, system, object, etc., usually cleverly or using imagination.]

⇒ Old French engin (means machines like a catapult in war.)

⇒ medieval English engin (means machines in war.)

⇒ English engine (means military machines.)

⇒ English engine'er (=engineer means a constructor of military machines in war)

⇒ civil engineer [who works for the design of civilian structures such as bridges and buildings matured as a technical discipline. (Also, together with the term of civil engineer, the term of "civil engineering" was coined to incorporate all things civilian as opposed to military engineering in 1771)]

⇒"engineer" and "engineeing," are used mainly in the meanings of "non-military engineers" and "non-military engineering," respectively.

⇒ Latin *ingeniator*

⇒*Old French engigneor*

⇒ French *ingénieur* (*At present,* the verb of French *ingénieur* is *s'ingénieur* that has the meaning of: "*to tax one's ingenuity, to employ all one's wits, to contrive; or to put in work all the resources of one's talent or one's wit for making an action, to attain a goal*" (This meaning is, in Japanese, as follows:: *創意を駆使する、あらゆる才能を働かす、考案･工夫･発明する;又は、目的を達成するために、行動を起こし、知性、知力、才能のすべてを発揮する*).

Engineering education in Japan, started in 1873, was introduced in the journal: "Nature", vol.16, pp.44-45, May 17, 1877.

★ The Ministry of Public Works, which was founded in 1870 for promotion of industry in Japan, was thinking of how to learn knowledge and skills for engineering from the United Kingdom and other countries in order to catch up with them. Then, Henry Dyer, M.A. B.S., (1848 – 1918; graduated as the best and brightest student in the civil and mechanical course in the faculty of arts of the Glasgow University, Scotland, in the fall of 1872 Glasgow), was invited as the first principal of the Imperial College of Engineering (founded in Tokyo in 1871 and officially opened in October 1873 to its inaugural freshman class); the former body of the present engineering faculty of the University of Tokyo).

When Dyer was a student of the University of Glasgow, Glasgow was famous as the birthplace of the industrial revolution and Prof. William Thomson (Lord Kelvin) was a well-known professor of the Glasgow university as a scientist of the discoverer of the "Thomson effect and heat", and also as an engineer of the inventor of several technologies related to submarine communication cables and others. By the influence of Prof. L. D. B. Gordon of the first professor of the civil and mechanical course, Prof. W. Thomson, and Prof. W. J. M. Rankine (Prof. Gordon's successor and Dyer's supervisor) of the civil and mechanical course, some engineering-oriented subjects for the work or activity of the engineers were taught at that time.

★ Dyer at age 25 arrived at Yokohama, near Tokyo, Japan, on June 3,1873. In the ship came to Japan from the UK, Dyer designed and crafted a new engineering education system of 6 years of the College, by merging his

studying experiences in Glasgow, the technology-oriented education in France and Germany, and the apprenticeship-oriented education in the UK except in the University of Glasgow. One of the noteworthy features of Dyer's challenges from the view-point of pedagogy is to involve that the engineering education with a focus on "what students learned" is indispensable.

★ In 1877, taking into account the above meanings of both Latin ingenium and French s'ingénieur, Dyer pointed out that an engineer is a person who taxes his ingenuity for seeking to design an effective solution to any problem, in a very wide implication and meaning, and also that such an engineer should be given the fourth professional position, next to the professionals of priests, lawyers, and doctors established already at that time in the United Kingdom, and also must be so in Japan.

★ In 1879, Dyer also pointed out, if in the use of the present words, that the engineering graduates of the College must acquire the engineers' distinctive competencies, together with the educational underpinnings, through leaning by doing, from fundamentals to specialization, including engineering practices in factories and laboratory experiments, in the College, and also acquire the engineering contextual knowledge and skills such as the Arts, Humanities, and Social sciences (AHS in short), by viewing the fine arts, or by reading books related to AHS, by self-study, outside the class, even after the graduation of the College, in order to broaden the outlook of the engineering graduates.

★ ***Remark 1***: ***In the Cambridge Advanced Leaner's Dictionary***, ***"engineering" is described as "the work of an engineer, or the study of this work," and "engineer" is described as "1. a person whose job is to design or build machines, engines or electrical equipment, or things such as roads, railways or bridges, using scientific principles.***

In the Oxford Advanced Leaner's Dictionary, "engineering" is described as "the activity of applying scientific knowledge to the design, building and control of machines, roads, bridges, electrical equipment, etc."; and "(also, engineering 'science) the study of engineering as a subject." (Note: the subject is an area of knowledge studied in a school, college, etc.)

In the Collins COBUILD Dictionary, "engineering" is described as "the work involved in designing and constructing engines and machinery, or structures such as roads and bridges"; and also as "the subject studied by people who want to do this work".

In the Random House Webster's unabridged dictionary, "engineering" is described as "1. the art or science of making practical application of the knowledge of pure sciences, as physics or chemistry, as in the construction of engines, bridges, buildings, mines, ships, and chemical plants. 2. the action, work, or profession of an engineer. 3. skillful or artful contrivance, manufacturing."

***In the United States*, the agency to certify engineering education programs is the Accreditation Board for Engineering and Technology (ABET). It defined, in 1985, "engineering " as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind."**

***The agency to certify engineering education programs in the United Kingdom* is the Engineering Council (EC-UK). In EC-UK, "engineering " was defined to be a profession directed towards the skilled application of a distinctive body of knowledge, based on mathematics, science and technology, integrated with business and management, which is acquired through education and professional formation in a particular engineering discipline."**

However, at present, the forward of the document of "UK Standard for Professional Engineering Competence" in www.engc.org.uk, begins with the following noteworthy sentences: "Professional engineering is not just a job – it is a mindset and sometimes a way of life. Engineers use their judgment and experience to solve problems when the limits of scientific knowledge or mathematics are evident. Their constant intent is to limit or eliminate risk. Their most successful creations recognize human fallibility. Complexity is a constant companion."///

In the International Engineering Alliance (IEA, in short)'s document of "Graduate Attributes and Professional Competencies" (IEA's GA&PC profiles, in short), which was approved on June 18, 2009 in the IEA Meetings called the EMF Kyoto 2009, "engineering" is re-defined as follows:

- ***Engineering is an activity that is essential to meeting the needs of people, economic development and the provision of services to society.***
- ***Engineering involves the purposeful application of mathematical and natural sciences and a body of engineering knowledge, technology and techniques.***
- ***Engineering seeks to produce solutions whose effects are predicted to the greatest degree possible in often uncertain contexts, where the solution means an effective proposal for resolving a problem, taking into account all relevant technical, legal, social, cultural, economic and environmental issues and having regard to the need for sustainability.***
- ***While bringing benefits, engineering activity has potential adverse consequences.***
- ***Engineering therefore must be carried out responsibly and ethically, use available resources efficiently, be economic, safeguard health and safety, be environmentally sound and sustainable and generally manage risks throughout the entire lifecycle of a system.***

Key words (1)

★ ***Engineering knowledge*** ***is based on fundamental*** ***engineering sciences***, ***engineering specialist knowledge*** ***and*** ***engineering contextual knowledge***.

★ ***Engineering fundamentals*** ***is a systematic formulation of engineering concepts and principles based on mathematical and basic sciences to support applications.***

★ ***An engineering specialization*** ***is a generally-recognized practice area or major subdivision within an engineering discipline, for example Computer Engineering or Electronics within Electrical and Computer Engineering; the extension of*** ***engineering fundamentals*** ***to create theoretical frameworks and bodies of knowledge for engineering practice areas.***

★ ***Engineering sciences*** ***includes*** ***engineering fundamentals*** ***that have roots in the mathematical and physical sciences, and where applicable, in other natural sciences, but extend knowledge and develop models and methods in order to lead to applications and solve problems, providing the knowledge base for*** ***engineering specializations***.

★ ***Engineering specialist knowledge*** ***is the knowledge associated with an*** ***engineering specialization***.

★ ***Engineering contextual (Complementary) knowledge*** ***is disciplines other than engineering, basic and mathematical sciences, that support engineering practice, enable its impacts to be understood and broaden the outlook of the engineering graduate.***

Keywords (2)

★ ***Engineering technology**, called **technology** simply, is **an established body of knowledge**, with associated tools, techniques, materials, components, systems or processes that enable a family of practical applications, and that relies for its development and effective application on engineering knowledge and competency.*

★ ***Engineering Activities** include but are not limited to: design; planning; investigation and problem resolution; improvement of materials, components, systems or processes; engineering operations and maintenance; project management; research, development and commercialization.*

★ *Typical engineering activity requires several **roles** including those of the **engineer** (professional engineer, **PE**), **technologist** (engineering technologist) and **technician** (engineering technician). These **roles** are defined by their distinctive competencies and their level of responsibility to the public. There is a degree of overlap between **roles**. The distinctive competencies, together with their educational underpinnings, are defined in the **IEA GA&PC profiles**. ///A comment from a typical textbook in USA: Although it is possible for engineers to work alone, more commonly they work with a group of support personnel. The engineer serves as innovator, creator, designer, decision-maker and leader of the engineering team including **technologists**, **technicians** and **other workers** like **crafts-persons** as support personnel.///*

For an example description about engineers: Extracts from Paul H. Wright, "Introduction to Engineering", Third Edition, John Wiley & Sons, Inc., 2002

***Engineer** is a specialist engaged in the profession of engineering.*

*The engineer's knowledge comes not only **from study**, but also **from experience and practice**. It must be applied **with the professional discretion and judgment**.*

*A **scientist** is lucky if he or she **makes one real creative addition to human knowledge** in his or her whole life, **and may never do so**. On the other hand, an **engineer** has, by comparison, **almost limitless opportunities of creating dozens of original designs, methods, systems, and devices** which are the result of the scientific knowledge, and has the satisfaction of seeing them become working realities.*

*In a typical case where engineer serves in the engineering team including **technologists**, **technicians** and **crafts-persons** as support personnel;*

***Engineers' roles**: Conceptual design, research, project planning, product innovation, system development, supervision of technologists, technicians, and crafts-persons. Four or more years of post-secondary professional education is required for engineers.*

***Technologists' roles :** Routine product development, construction supervision, technical sales, hardware design and development, coordination of work force, materials, and equipment, supervision of technicians and crafts-persons. Three or more years of post-secondary professional education is required for technologists.*

***Technicians' roles :** Drafting, estimating, field inspections, data collection, surveying, technical writing. Two or more years of post-secondary professional education is required for technicians.*

***Crafts-persons' roles :** (skilled workers who produce the materials and products or facilities specified by the design) Uses hand and power tools to service, maintain, and operate machines or products useful to the engineering team.*

3. Substantial equivalency of accredited engineering education programs in the WA signatories: ABET, CEAB, ECUK, IEAust, … , JABEE, ABEEK, IEET, BEEM, …

- ✓ ***WA graduates***
- ✓ ***WA's GA profile: WA graduate attributes, WA attributes or WA outcomes***
- ✓ ***WA's Knowledge profile***
- ✓ ***WA exemplar***

The fundamental purpose of engineering education is to build a knowledge base and attributes to enable the graduate to continue learning and to proceed to formative development that will develop the competencies required for independent practice. (IEA's GA&PC profiles)

★ ***The Washington Accord (WA, in short) is an international agreement among bodies (called signatories, full members) responsible for accrediting engineering education degree-granting programs. It recognizes the substantial equivalency of programs accredited by those bodies and recommends that graduates of programs accredited by any of the signatory bodies be recognized by the other bodies as having met the academic requirements for entry to the practice of engineering. The graduates of the programs accredited by any of signatory bodies of WA are called WA graduates.***

Signatory status of WA : 15 signatories as of July 1, 2013

ABET (Accreditation Board for Engineering and Technology, USA;1989),
ECUK (Engineering Council, UK;1989),
CEAB (Canadian Engineering Accreditation Board, Canada; 1989),
IEAust (Institute of Engineers Australia; 1989),
Engineers Ireland (1989),
IPENZ (Institute of Professional Engineers NZ; 1989),
HKIE (The Hong Kong Institute of Engineers; 1995),
ECSA (Engineering Council of South Africa; 1999),
JABEE(Japan Accreditation Board for Engineering Education; 2005),
IES (Institute of Engineers Singapore; 2006),
ABEEK(Accreditation Board for Engineering Education of Korea; 2007),
IEET (Institute of Engineering Education Taiwan; 2007),
BEM (Board of Engineers Malaysia; 2009),
MUDEK (Turkey; 2011),
AEER (Association for Engineering Education of Russia; 2012),

Provisional status of WA: As of July 1, 2013: BAETE(Bangladesh), CAST(China), NBA(India), PEC(Pakistan), PTC(Philippine), and IESL(Sri Lanka).

★ ***The ABET is a non-government organization that accredits post-secondary education programs in "applied science, computing, engineering, and technology (in the meaning of engineering technology)" in USA. The ABET was established in 1932 as the Engineer's Council for Professional Development (ECPD) by several engineering societies in USA. In 1980, its name was changed from the ECPD. At present, the ABET has the four accreditation commissions: Applied Science Accreditation Commission (ASAC),Computing Accreditation Commission (CAC), Engineering Accreditation Commission (EAC), Technology Accreditation Commission (TAC) within it. Each commission has different accreditation criteria.***

The engineering education degree-granting programs of HEIs in USA are examined, on the application base of the programs' side, using the ABET's engineering criteria of "outcomes base – what students learned-, and then are accredited by the ABET-EAC, if the programs satisfy the present criteria.

The ABET is one of the founding signatories of the WA. The engineering design is the most typical part of the engineering activity, and, indeed, the ABET's engineering criteria request an HEI with an engineering education program to be accredited by the ABET-EAC to design the program's curriculum that students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

★ The International Engineering Alliance (IEA, in short) is an umbrella for six international agreements:

WA (Washington Accord) : WA graduates (candidates for engineers)
SA(Sydney Accord): SA graduates (--- for engineering technologists)
DA(Dunlin Accord): DA graduates (--- for engineering technicians)
International Professional Engineers Agreement
International Engineering Technologist Agreement
Professional Engineers (Regional Agreement) (APEC Engineers)

governing mutual recognition of engineering qualifications and professional competence, and the IEA aims at contributing to development and recognition of good practice in engineering and engineering education.

★ Graduate attributes form a set of individually assessable outcomes that are the components indicative of the graduate's potential to acquire competence to practice at the appropriate level. The outcomes are clear, succinct statements that describes what students are expected to know and be able to do by the time of graduations.

★ Graduate attributes in the IEA's GA&PC profiles are called IEA's GA profiles.

★ IEA's GA profiles consist of three profiles called WA's GA profile, SD's GA profile, and DA's GA profile. The WA's GA profile is made up of the following twelve attributes, called WA graduate attributes, WA attributes or WA outcomes:

WA's GA profile: WA graduate attributes

Engineering programs must demonstrate that their students attain all of the WA graduate attributes described below:

Attribute 1) Apply knowledge of mathematics, science and engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

Attribute 2) Identify, formulate, research literature and analyze complex problems reaching substantiated conclusions using first principles of mathematics, etc.

Attribute 3) Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration of public health and safety, cultural, societal and environmental considerations.

Attribute 4) Conduct investigations of complex problems using research-based knowledge and methods, including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

Attribute 5) Create, select and apply appropriate techniques, resources and modern engineering and IT tools, including prediction and modeling, to complex engineering activities, with an understanding of their limitations.

Attribute 6) Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and consequent responsibilities relevant to professional engineering practice.
Attribute 7) Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate knowledge and need for sustainable development.
Attribute 8) Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate knowledge and need for sustainable development.
Attribute 9) Function effectively as an individual, and as a member or leader of diverse teams and in multi-disciplinary settings.
Attribute 10) Communicate effectively on complex engineering activities with the engineering community and society at large, such as … comprehend and write effective reports and design documentation.
Attribute 11) Demonstrate knowledge and understanding of engineering management principles and apply these to own work and as a member or leader of a team, to manage projects and in multi-disciplinary environments.
Attribute 12) Recognize the need for, and have the preparation and ability to engage in independent life-long learning in the broadest context of technological change.

★ ***The IEA's Knowledge profile in the IEA's GA&PC Profiles consists of three parts called WA's Knowledge profile, SA's Knowledge profile, and DA's Knowledge profile. The WA's Knowledge profile is the profile made up of the following knowledge 1), 2), … , and 8) that WA graduates should acquire in the engineering education degree-granting program accredited by any signatory of WA:***

Knowledge 1) Systematic, theory-based understanding of the natural sciences applicable to the discipline.
Knowledge 2) Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modeling applicable to the discipline.
Knowledge 3) Systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
Knowledge 4) Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas of the discipline; much at the forefront of knowledge.
Knowledge 5) Knowledge that supports engineering design in a practical area.
Knowledge 6) Knowledge of engineering practice (technology) in the practice areas of the discipline.

Knowledge 7) Comprehension of role of engineering in society and identified issues in engineering practice in the discipline: ethics, public safety, impacts of engineering activity: economic, social, cultural, environmental, and sustainability.
Knowledge 8) Engagement with selected knowledge in the research literature of the discipline.

★ ***A program that builds this WA's Knowledge profile and develops the twelve WA graduate attributes is typically achieved in 4 to 5 years of study, depending on the educational level of students on entry to HEIs after graduation from the high schools.***

★ ***Remark 2: The use of "involves" in the explanation sentence of "Engineering involves the purposeful application of mathematical and natural sciences and a body of engineering knowledge, technology and techniques." in the IEA's GA&PC profiles, implies that the engineering also involves the purposeful application of appropriate knowledge and skills not only of arts, humanities (including human values), and social sciences, but also of business and management, as are suggested in Attribute 6), Attribute 11) and Knowledge 7). The above two kinds of appropriate knowledge include the engineering contextual (complementary) knowledge explained in the slide of page 14.///***

★ ***The engineering problem is defined to be one that exists in any domain that can be solved by the application of engineering knowledge and skills and generic competencies, and the complex engineering problem is defined to be engineering problems which cannot be resolved without in-depth engineering knowledge, much of which is at, or informed by, the forefront of the professional discipline, and have some or all of the following characteristics:***

1) ***involve wide-ranging or conflicting technical, engineering and other issues.***
2) ***have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.***
3) ***requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.***
4) ***involve infrequently encountered issues.***
5) ***are outside problems encompassed by standards and codes of practice for professional engineering.***
6) ***involve diverse groups of stakeholders with widely varying needs,***
7) ***have significant consequences in a range of contexts.***
8) ***are high level problems including many component parts or sub-problems.***

★ *The* ***IEA Meetings, Seoul, Korea 2013*** ***was held from June 17 to June 21 at the Millennium Seoul Hilton Hotel. In the WA's session in the meetings, it was recognized unanimously that the WA's GA profile with the WA's Knowledge profile is an exemplar (i.e., a typical or good example), but not any standard, as the current Rules and Procedures of the WA are requiring a full signatory's graduate attributes to be substantially equivalent to the Accord exemplar. In this talk, for the sake of convenience, the WA's GA profile with the WA's Knowledge profile is called the WA's GA exemplar, or simply the WA exemplar. However, the question of "What is an allowable range or degree of substantial equivalency to the WA exemplar?" remains as a continuing issue to be discussed in the WA's session, still in the future.***

★ ***The WA exemplar seems to involve an intention or implication of raising the academic level of the engineering education, because it contains the striking terms of "research" (not just investigation), "apply contextual knowledge", "apply ethical principles", and "complex" (in the meaning of WA's definition). Indeed, in the WA's session in the IEA Meetings, Seoul, Korea 2013, it was reported that the graduate attributes of the WA exemplar are regarded equivalently as those of the second cycle (master-degree level) of the Bologna process in European countries, from the view-point of the usage of the words, and then it was decided that the actual action of discussion, adjustment and documentation about the details of correspondence between the IEA's GA profiles and the Bologna process will start in a new WG in the WA.***

IEA's graduates

Common stem

Engineers	Technologists	Technicians
WA graduates	SA graduates	DA graduates
WA graduate attributes (outcomes)	SA graduate attributes (outcomes)	DA graduate attributes (outcomes)
Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solutions of complex engineering problems.	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to defined and applied engineering procedures, processes, systems or methodologies.	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to wide practical procedures and practices.

2009 version

Ranging information

to the conceptualization of engineering models (2008 version)

★ *In 2008, the CEAB in Canada changed its then engineering criteria into its present engineering criteria of outcomes base – what students learned –, by taking in advance many of the contents and contexts of the WA graduate attributes in the 2008 draft version of the WA exemplar. So, the present criteria seem to be along the intention or implication of the WA exemplar.*

★ *On October 30, 2011, the ABET modified the famous engineering criteria EC2000 of outcomes base – what students learned – (adopted as an innovative change in 1997, after the engineering community's intense discussion on questions about the appropriateness of the ABET's then engineering criteria of input base – what material is taught – in the mid-1990s in USA) into its present engineering criteria of outcomes base – what students learned –. Since the WA exemplar is a typical or good example but is not any standard, the present criteria seem to be in a range of substantial equivalency of the WA exemplar, although the present criteria do not contain the striking terms such as "research", "complex", "apply contextual knowledge", and "apply ethical principles" in the WA exemplar.*

★ *In 2012, the JABEE in Japan changed the start-up engineering criteria of "outcomes base – what students learned – " into the present engineering criteria of "outcomes base – what students learned – ", by taking account of the contents and contexts of the WA exemplar. Since the JABEE's start-up, in order to make smooth progress of the accreditation process, additional and/or supplementary information necessary to avoid the possibility of causing misapprehension about the JABEE's accreditation criteria has been included in the annual document of the Procedures and Methods of Examination and Accreditation so far and will be continued until the next improvement or change of the criteria themselves. The present criteria seem to be harmonized substantially equivalently to the WA exemplar, under the recognition that the WA exemplar is a typical or good example.*

The JABEE is currently servicing the Dual-Level Accreditation (D.L.A) which means the JABEE's engineering criteria of being two-hold: one is for accrediting engineering education bachelor-degree-granting programs in HEIs of 4 years and the other is for accrediting engineering education master-degree-granting programs in graduate schools of 2 years.

★ For your information:** **At present, the ABET's criteria for masters level engineering education degree-granting programs are completion of a program of study satisfying the general criteria for Bachelor's degree level engineering programs, one academic year of study beyond the Bachelor's degree level, and an engineering project or research activity resulting in a report that demonstrates both mastery of the subject matter and a high level of communication skills. <u>At present, however, the students in the programs can get the Master degree, but not get the Bachelor degree</u>.

D.L.A is currently prohibited by the ABET-EAC, but the ABET is now watching and listening closely to the discussions following the release of the National Academy of Engineering Engineers of 2020 reports in USA.///

ABET
Leadership and Quality Assurance in Applied Science, Computing Engineering and Technology Education

CommunityMatters™

A Monthly Newsletter for the ABET Community

September 2006

InsideABET

Call for Comments on Dual-Level Accreditation

ABET is watching and listening closely to the discussions following the release of the National Academy of Engineering *Engineer of 2020* reports, particularly those regarding accreditation at both the bachelor's and master's levels. This practice is currently prohibited by the Engineering Accreditation Commission (EAC) of ABET.

Specifically, the reports recommend that the bachelor's degree "be considered as a pre-engineering or 'engineer in training' degree," rather than the first professional degree, as the bachelor's is widely considered now.

Many in the engineering community favor the master's degree as the first professional degree, citing the need to both enhance the status of the engineering profession and to enable new engineers to enter the profession with the breadth and depth of knowledge many feel is required in today's increasingly global economy.

Others argue for the bachelor's to remain as the first professional degree out of concern for creating yet another roadblock in the U.S. engineering pipeline.

Ultimately, ABET must respond to its core constituencies — the 28 professional societies that comprise it and the academic institutions that invite it to assess their programs. ABET will not be a "driver" in this regard, but it must be responsive to the needs of its constituents. That may mean being a facilitator for those programs who seek to change and for the profession as a whole, should it decide to move in the direction of the *2020* recommendations.

ABET needs to hear from you on this issue. Should the EAC prohibition on dual-level accreditation be removed? Please send your comments to ABET President Richard

– continued on page 2

VolunteerSpotlight

Kay Schulze

Kay G. Schulze, Ph.D., recently completed her service as the Chair of the Computing Accreditation Commission (CAC) for the 2005-2006 accreditation cycle. Like her predecessors, Kay oversaw all of the CAC's activities, setting its meeting agendas and editing final statements to the institutions. However, during her tenure, Kay also found a way to foster timeliness among members of her commission.

Before CSAB became part of ABET in 2000, the society completed draft statements to the institutions based on the previous fall's accreditation visits by mid-January, thereby allowing final draft statements to be completed by late May. During the past few years, though, the commission became lax about this practice, which frequently led to harrowing efforts on the commission leaders' parts as they prepared for the Summer Commission Meeting, when accreditation actions are discussed and finalized. Kay experienced this last-minute rush often over her five years on the CAC Executive Committee and was determined to make it a thing of the past.

"In the spirit of ABET's commitment to continuous self-examination, we made a conscientious attempt to enhance the timeliness of providing feedback to our programs and institutions," she said.

Kay's solution was to revise the timeline for much of the accreditation cycle and to use a spreadsheet to track the cycle's progress. If the team chairs neglected their deadlines, Kay would take the time to personally send them a "ping," a computing term meaning to send out a signal to see if there are signs of activity from a piece of hardware or, in this case, the volunteer receiving the e-mail message. Not only were Kay's reminders effective, but they contributed to the CAC finishing all of their final statements for the 2005-2006 accreditation cycle by the end of May — an all-commission record in recent ABET history — and to smooth sailing into CAC's business meetings in late July.

Kay Schulze is a professor and the Chair of the Computer Science Department at the United States Naval Academy in Annapolis, MD, where she has been a civilian faculty member for 17 years.

LookAhead

Sept. 22 — ABET Board Executive Committee Meeting in Baltimore, MD

Sept. 29 — Registration deadline for the Oct. 24 workshop in Tampa, FL
— Pre-registration deadline for the 2006 Commission Summit and the 2006 ABET Annual Meeting in Tampa, FL

Oct. 25 — 2006 Commission Summit featuring "A PEV's Eye View"

Oct. 26-27 — 2006 ABET Annual Meeting — "The 3rd ABET International Congress on Education, Accreditation, and Practice"

4. The engineering is dynamic and constantly changing, especially in fields such as electronics and info-communications engineering.

The idea of "design for the value and design for the thing as its realization" will change the existing engineering education creatively and innovatively.

The engineering design plays
the most important part of the engineering activity.

★ ***In the IEA's GA&PC profiles,***

➢ ***Engineering design is the systematic process of conceiving and developing materials, components, systems and processes to serve useful purposes.***

➢ ***Design may be procedural, creative or open-ended and requires application of engineering sciences, working under constraints, and taking into account economic, health and safety, social and environmental factors, codes of practice and applicable laws.***

➢ ***Engineering design knowledge is knowledge that supports engineering design in a practice area, including codes, standards, processes, empirical information, and knowledge reused from past designs.***

➢ ***Engineering design ability is an ability to design solutions for complex engineering problems and to design systems, components or processes that meet specified needs with appropriate consideration of public health and safety, cultural, societal and environmental considerations.***

★ ***Remark 3: The curriculum requirements of the ABET's engineering criteria specify subject areas appropriate to engineering but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution. The professional component must include:***

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences.

(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Students must be prepared for engineering practice through a <u>curriculum culminating in a major design experience</u> based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

One year in the ABET's engineering criteria is the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation. ///

★ Remark 4: The curriculum of the Electrical Engineering Bachelor of Science Program, accredited by the ABET-EAC, in the Department of Electrical and Computer Engineering, College of Engineering, University of Illinois at Chicago, shows one of typical examples of senior engineering design education of HEIs in USA. The curriculum incorporates design projects in the student's experience starting from the freshman year and culminating in a capstone design project in the senior year. The capstone design project requires the students to undertake a significant group design that enriches their knowledge in practical aspects of engineering principles and methodologies, and the project solves realistic problems and the results are presented in an exposition, as shown in the following course structure made up of two parts:

ECE 396 - Senior Design I (in the first semester of the senior year): Credit 2.
Introduction to the principles and practice of product design: specifications, evaluation of design alternatives, technical reports, and oral presentations.
Prerequisite: ENGL 161 (English language proficiency) and senior standing

Topics:
- ✓ ***Organization into groups and selection of a design project***
- ✓ ***Discussion of design principles, objectives, project management, cost***
- ✓ ***Research culminating in a an initial design proposal***
- ✓ ***Completion of a "paper" design with a report and an oral presentation***

ECE 397 - Senior Design II (in the second semester of the senior year): Credit 2.
Application of engineering principles and optimization to the solution of the design problem initiated in Senior Design I. Implementation and testing of the design.
Prerequisite: ECE 396

Topics:
- ✓ ***Construction/simulation and testing of the design prototype based on the paper design carried out I ECE 396***
- ✓ ***Optimization of design to meet the specification including economic/production considerations***
- ✓ ***Final report and oral presentation***

///

★ ***Remark 5**: In the CEAB's engineering criteria , engineering design is explained to integrate mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs; and the design is explained as a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors; and also engineering design ability is as an ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.*

The CEAB's engineering criteria request an HEI with an engineering education program to be accredited by the CEAB to design the program's curriculum that must culminate in the significant design experience conducted under the professional responsibility of faculty licensed to practice, preferably in the jurisdiction in which the HEI is located. The significant design experience is based on the knowledge and skills acquired in earlier course work and it preferably gives students an involvement in team work and project management.

The CEAB's engineering criteria and the ABET's engineering criteria are common in positioning of the design education in the curriculum design.///

★ ★ ★ ***The following two articles are attracting our special interest in relation to causing a new wave in engineering education by introducing of the creative and innovative idea to engineering design education.***

I: The extracts partially from the essay entitled "From thing-creation to value-creation -- toward new innovation" (in the Journal Chemistry and Chemical Industry; vol.61-11, pp.1033-1034, November 2008), written in Japanese by Dr. Mutsuhiro Arinobu when he was Advisor of Toshiba Company. (Dr. Arinobu has become the President of the JABEE since May, 2013.)

II: The extracts partially from the Japan Association of Corporate Executives 's proposal on the title of "Toward the manufacturing and value creation to win in the global business – Market-oriented things- and values-creation" (The association's home page, June 24, 2011, written in Japanese)

Note: Correspondence between Japanese words and English ones;

mono, もの: thing, product (systems, components, processes: hardware, software, or hardware with built-in software)

mono-zukuri, ものづくり: creation of thing or things, thing-creation creation of product, product-creation

koto, こと: value (sometimes, story, service, …)

koro-zukuri, ことづくり: creation of value or values, value-creation creation of story, story-creation ///

The contents of I (translation from Japanese):

Our "consumption of service" exceeded the "consumption of things" already some years ago, and people's interest has been shifted from "richness in things" to "richness in mind".

For example, when PC and mobile phone became tools for mailing or internet browsing, the consumer "gets surprised or moved" and "feels richness and value" by using such "things". This means the "thing" is no more object for consumers, but "thing" is tool for consumer's value. In this way, "value" is realized by "thing", and such "value" can even induce further new values just like a chain reaction.

Therefore , engineers in today's industry are expected to design and develop the "thing" as "product", always thinking about its "value in realizing richness for the people and society" rather than simple differentiation of performance or function of the product.

For this, engineers should draw their vision on their desirable life and society, and image the requirement for the "new value" to improve the "richness of mind" and "quality of life". Then, engineers may design the various "value for people and society" and reflect it on the product design or necessary innovation.

Then, engineers can provide not only our "product" as "thing" but also as the "value", which is expected to create further new values in a way like "chain reaction". ///

***The contents of II** (translation from Japanese):*

"Value -creation" is the activity to provide <u>real customer-value</u> by deeply thinking about "what is the product which is asked by customers", and "what is wished by customers to do using the product".

"Value –creation" should be made by living in the real market and by thinking together with the people in the market and by using all kind of sensitivity.

Furthermore, unexpected and additional values and satisfaction for the customers can be created by thinking more deeply than the customers.

"Value-creation" is the opposite concept from "thing -creation". "Thing -creation" is the approach from the view of manufacturers' side and could be defined as the entrance of business.

To the contrary, "value -creation" is based on the view from the market side, which could be defined as the exit of business and applied for redesigning quality-standard, business-model, business-scenario, industrial design and service-design.

The strength of past Japan was "thing -creation" which used to be only available in Japan such as high fitting technology, high safety and security.

No doubt, Japan should continue to maintain this advantage in high technology, but at the same time, Japan add more value in the service using the product. The competitiveness of the product & service should be the target in the world.

In addition, the next two important relevant matters are pointed out:

✓ ***In order to strengthen the power to create new values in the industry, the new human resources who can***

1) ***understand the market with the ability to design both users' experience and business model,***
2) ***have bird's eye view on the market-change and have flexible and speedy response to it, and***
3) ***have leadership to involve people***

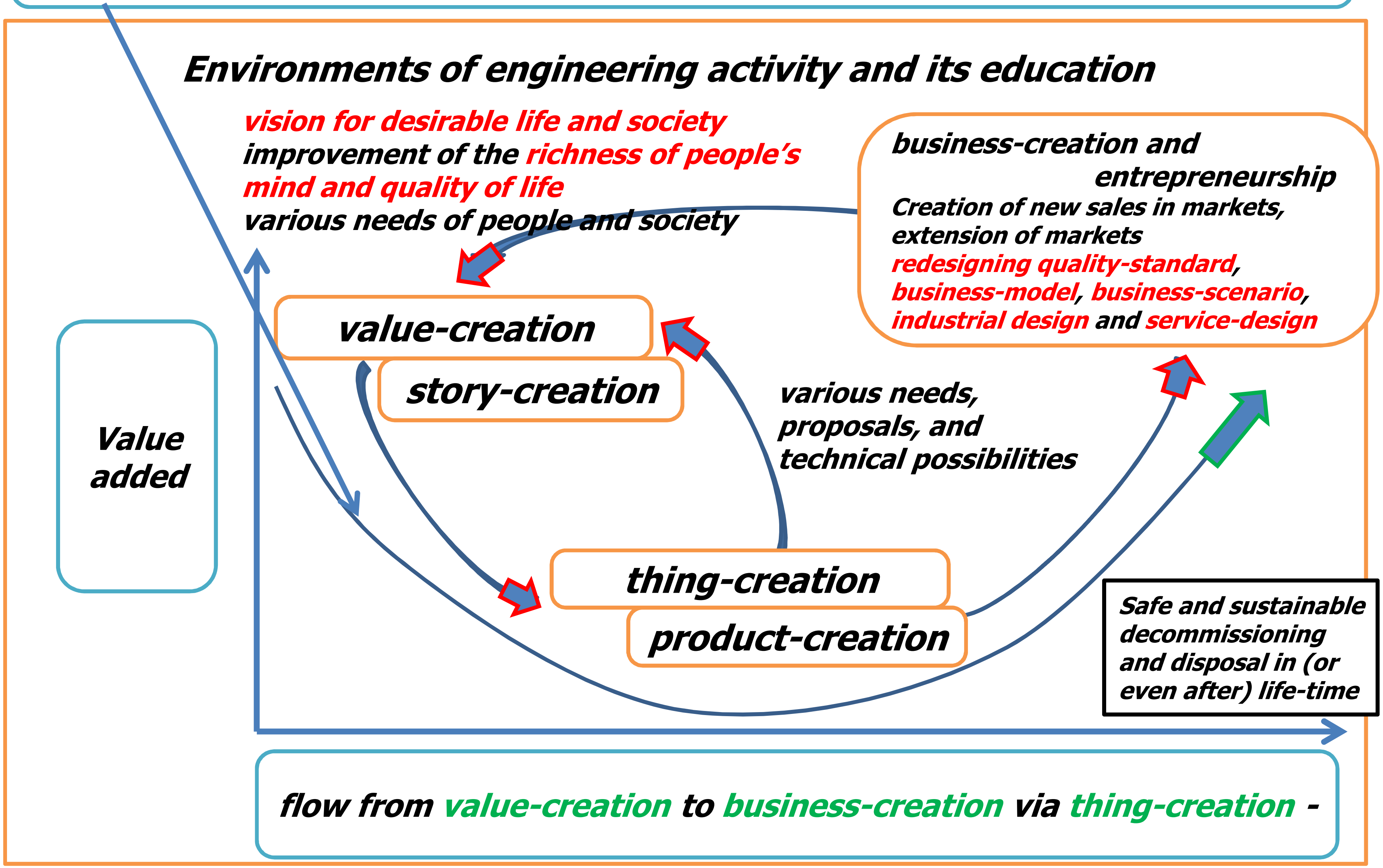
are required.

✓ ***In order to increase both things- and value-creation capacity in the industry, the new human resources who can***

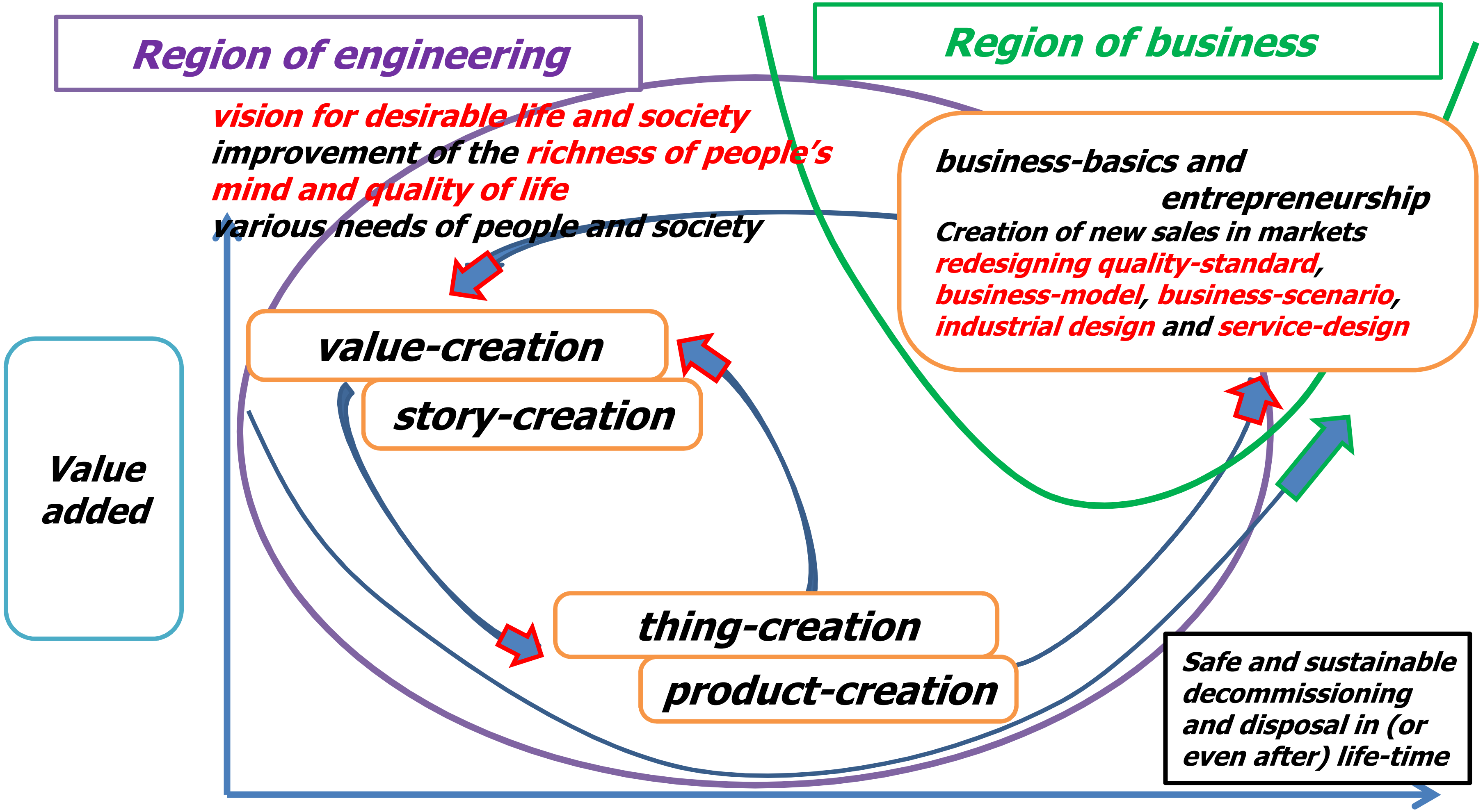
1) ***have always questions to usual and normal habits and trying to improve the society,***
2) ***have passion and patience, and***
3) ***have challenging mind and full of curiosity***

are required. ///

Smile-curve from value-creation to business-creation via thing-creation



Grasp of relationships among value-creation, thing-creation and business-creation for engineering design and its education



flow from value-creation to business-creation via thing-creation

★ ★ ★ ***The idea of "design for the value (koto, in Japanese)" and "design for the thing (mono , in Japanese) as the realization of the designed value" causes the change of the existing engineering education into an innovative one with program's curriculum culminating in the major team-based design education experience based on the process consisting of the following six phases, through the first and second semesters of the senior year, by applying the knowledge and skills acquired in earlier course work and those acquired in appropriately related course work in the first semester of the senior year. Hereafter, I call the process consisting of the following six phases the Arinobu design process (or the Arinobu design model), taking the implication of Arinobu's essay into consideration.***

1) to image always the "vision for desirable life and society", and to conceive the "value" for improving the "richness of people's mind and quality of life," and furthermore to design the "value" fulfilling various needs of people and society, taking account of multiple actual constraints such as economic, social, political, ethical, health and safety, cultural and environmental factors, codes of practice and applicable laws, and manufacturability and sustainability.

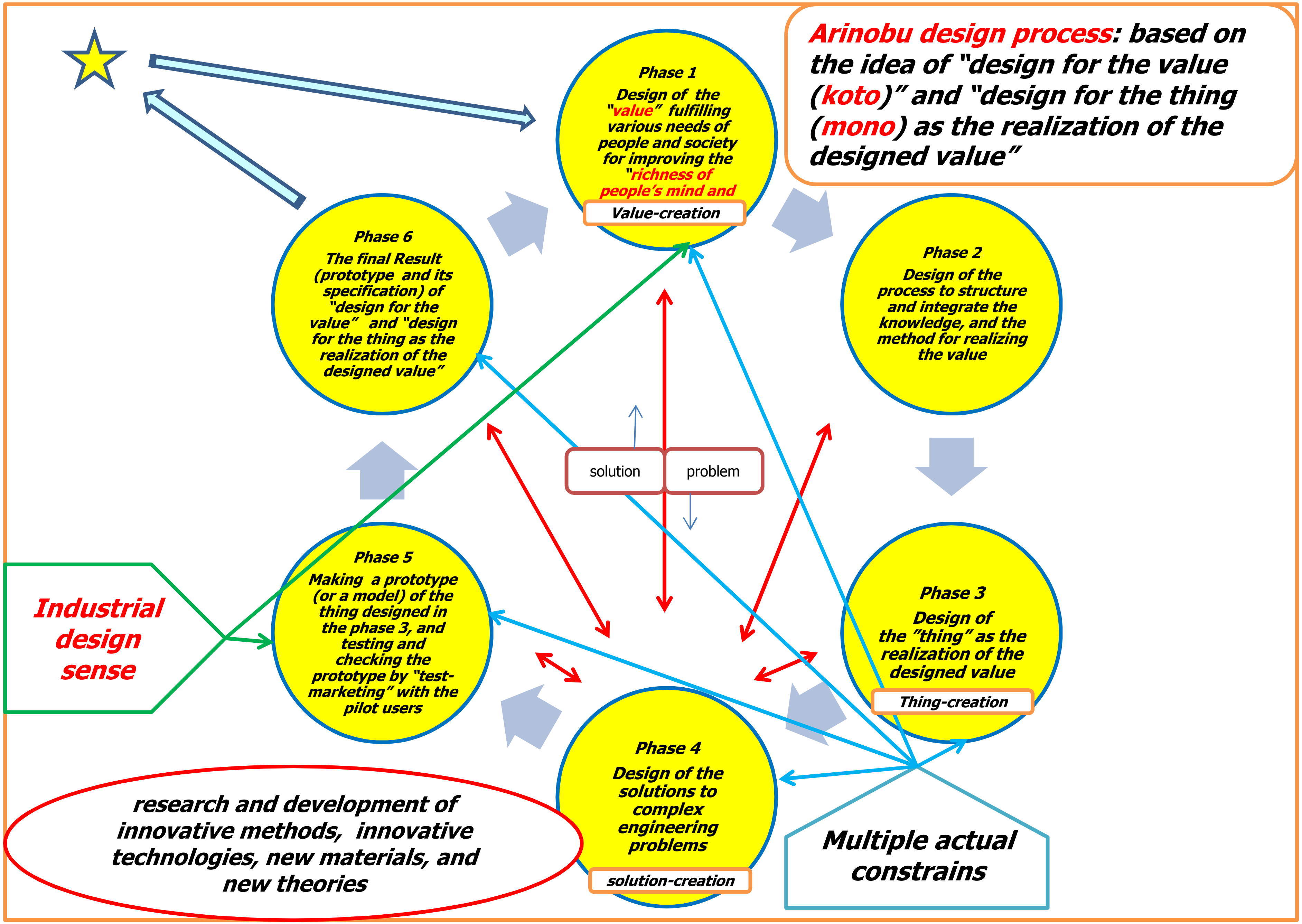
2) to design the process to structure and integrate the knowledge, and the method for realizing the "value".

3) to design the "thing" (system, components, processes; hardware, software or their combination) as the realization of the "value" under the multiple actual constraints, with creativity and innovation, and always satisfying the needs.

4) to design the effective solutions against various problems, including "complex engineering problems", generated (or encountered) concurrently in the above or following phases.

5) to make a prototype (or a model) of the "thing" designed in the phase 3), and to test and check the prototype by "test-marketing" with the pilot users. If there is no problem of the prototype, make the specification for detailed design and production of the "thing". If any problems remain, solve the problems and reflect it to the redesign and re-prototype of the "thing", and repeat this cycle.

6) to provide the prototype of the "thing" with the specification on detailed design and production, including the information on the final "thing" and also information on the "value" in its usage. (In general, in industries, the actual production is carried out by the team of technologists, technicians, and other workers under the management by the engineer or a group of engineers.)


Arinobu design process: based on the idea of "design for the value (koto)" and "design for the thing (mono) as the realization of the designed value"
Phase 1
Design of the "value" fulfilling various needs of people and society for improving the "richness of people's mind and
Value-creation
Phase 2
Design of the process to structure and integrate the knowledge, and the method for realizing the value
Phase 3
Design of the "thing" as the realization of the designed value
Thing-creation
Phase 4
Design of the solutions to complex engineering problems
solution-creation
Phase 5
Making a prototype (or a model) of the thing designed in the phase 3, and testing and checking the prototype by "test-marketing" with the pilot users
Phase 6
The final Result (prototype and its specification) of "design for the value" and "design for the thing as the realization of the designed value"
solution
problem
Industrial design sense
research and development of innovative methods, innovative technologies, new materials, and new theories
Multiple actual constrains

★ Remark 6:   One of the reasons why "<u>team-based course work</u> " has been emphasized in "engineering design as well as its education" is related to the emergence and consequences of cooperative norms in a team, which may be caused by the shared expectation of members in the team that must work together, to generate, suddenly, creative and innovative ideas available for overcoming the difficulty of problem-solving of an open-ended and ill-structured problem to be challenged, as synergistic effects of collaborative communications among the members through repeated team-meetings and then, as appropriate integration and selection of such available ideas, to achieve a common goal of developing multiple acceptable solutions of the problem and selecting the most effective one among them under multiple actual constraints.

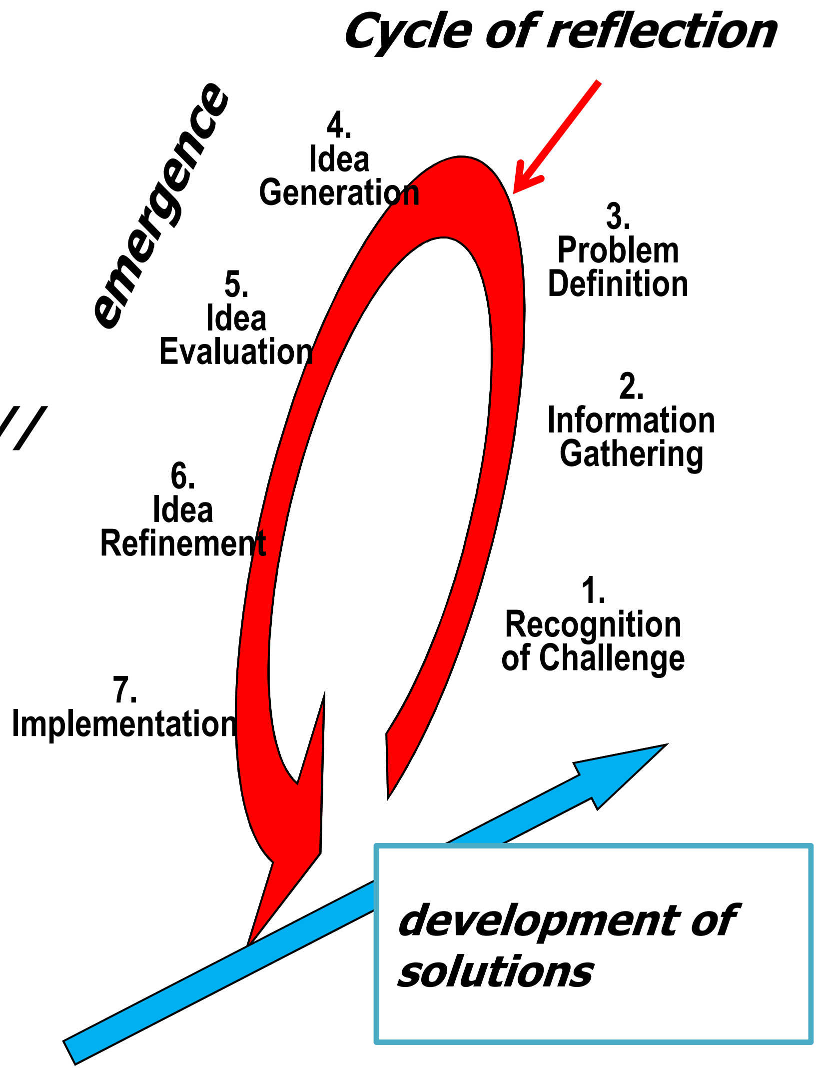
A key trigger for causing the emergence is believed to be the demographic heterogeneity of a team formation which takes account of incorporating people with different specialties and cultures but with ability of collaborative work toward common objectives into the team, through experimental research and experiences in many cases until now, <u>because there are at present no royal roads to yielding creative and innovative ideas available for overcoming the difficulty of problem-solving whenever we encounter complex engineering problems.</u>

------ Foot-note: Such a complex problem have multiple acceptable solutions, but the solutions can not normally be found by applying mathematical formulas or algorithms in a routine or structured way.///

★ ***Remark 7*: Students (engineers , as well) must always prepare themselves to brush up the ability of reflective thinking, in any stage of their learning, designing, researching and developing (i.e., the ability of rotating the "cycle of reflection" in the right-side figure in this slide) and also the ability of reflective practice made up of**

- reflection-in-action (solving problems as they are encountered), and

- reflection-on-action (periodically analyzing progress to learn and make changes), as in the use of Davis and Tompson in the following last reference.///



References;

- *J. Dewey, How We Think, New York (1933).*
- *Donald A. Schon, The Reflective Practitioner, New York(1983).*
- *Donald A.Schon, "Knowing-in-action: The new scholarship requires a new epistemology," Change, pp.27-34, 1995 (November-December).*
- *Denny Davis and Phillips Tompson, "Integrated Assessment Instruments for Engineering Design Education", Keynote speech, JABEE's "Good Practices of Capstone Engineering Design Education Symposium", (March 7 ,2009).*

★ Remark 8: There are the important supplements to the above six phases: The "value " realized by "thing " has the potential to produce further values like "chain-reaction". However it is difficult at the stage of its initial design to foresee all the new values produced by this chain-reaction. Often it is the users who find the unexpected joy and satisfaction with richness and new value, far exceeding the designed "value" to be realized by the "thing" which is usually explained in the product-manuals such as use-case of the product including various maintenances in the product's life time.

Therefore, engineers should always imagine or draw their vision on their "desirable life and society", and think about the "value" to improve the "richness of mind" and "quality of life" more intensively than the consumers and try to foresee the future needs of the users. <u>So, students in engineering schools are always required to</u> broaden the level (i.e., breadth and depth) of culture about appropriate knowledge and skills of AHS (Arts, Humanities - including Human values -, and Social sciences) and about those of entrepreneurship and business basics, in class, or by active learning, by internets and by reading books and magazines, in every opportunity, in addition to their acquiring of appropriate knowledge and application skills of mathematical and natural sciences, and a body of engineering knowledge, technology and techniques related to their fields of specialty. Indeed, such culture and specialty are inevitable for working long as ambitious and active engineers with challenging minds of full of curiosity and with creative, innovative and/or entrepreneurial minds.

As all of you know, today, consumers have preference for the good design with aesthetic attractiveness for shape, size or color under the products with similar function, performance or mechanism, which causes often difference in product sales amount. Aesthetics is a branch of AHS, and the industrial design has already been established as a subject in the fusion area of the engineering design and the aesthetics. In 1970s, German industrial designer Dieter Rams introduced the idea of sustainable development and of obsolescence being a crime in design. And, he asked himself the question of "Is my design good design?". The answer formed his now celebrated ten principles which are called "The Ten Principles of Good Design". The first three principles of them are:

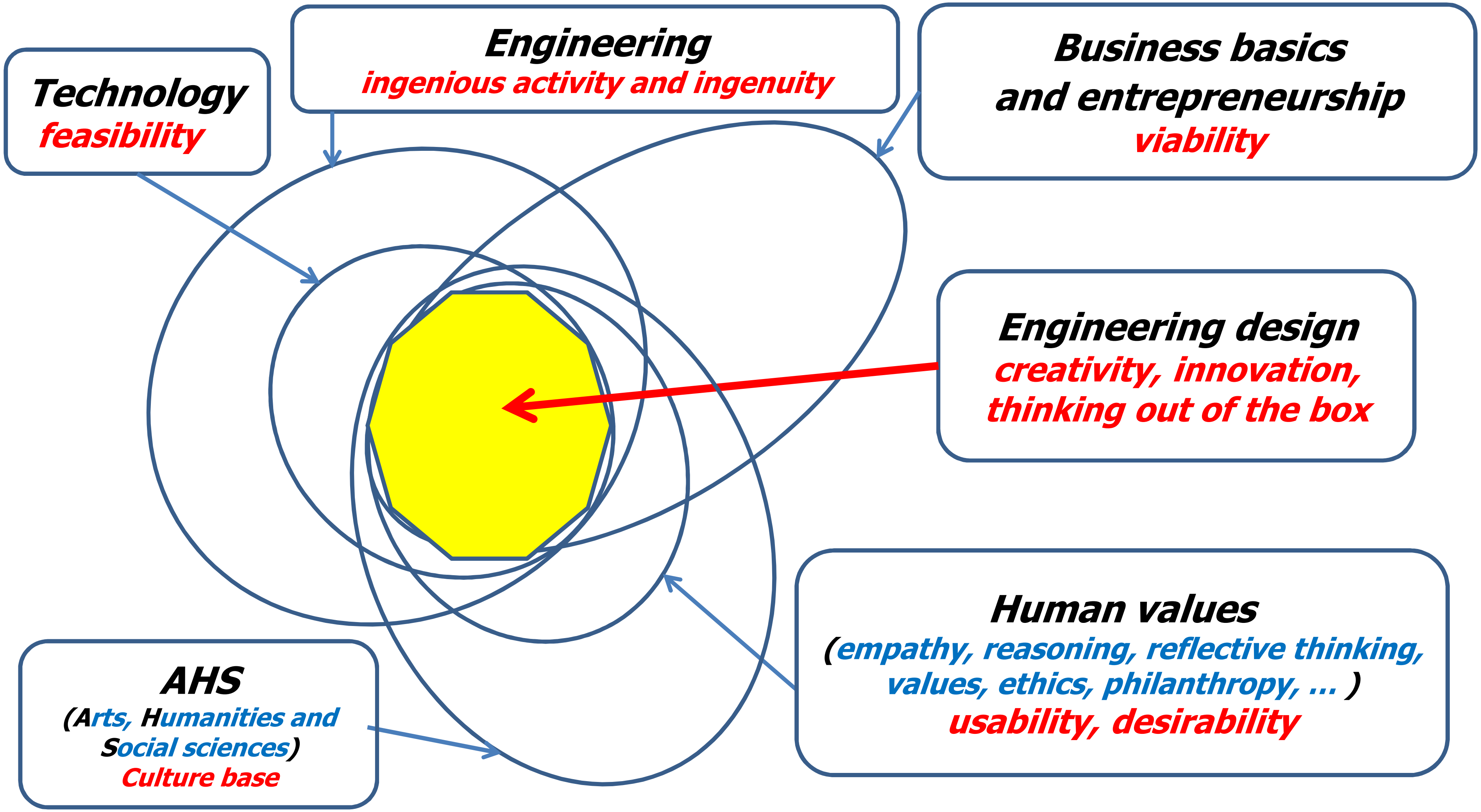
1) Good design is innovative;

2) Good design makes a product useful; and

3) Good design is aesthetic.

Interestingly, the special trophy of beautifully designed tree-like structure to each of the winners for the Queen Elizabeth Prize for Engineering was created by 17-year old Jennifer Leggetti from Tonbridge, the winner of the national 'Create the Trophy' competition (held December 5, 2012 at the Science Museum, London) for young people with interests in Science, Engineering, Design, Art and Architecture to design the trophy for the Queen Elizabeth Prize for Engineering, in UK. Please see the judge criteria and the selection reasoning of the competition in www.qeprize. Some of "The Ten Principles…" were taken into consideration in the selection. ///

★★★ ***The relationship of engineering design and its related disciplines is grasped in the following conceptual image. This is my modification of an image used in the lecture power-point slides of James D. Plummer, Dean of Engineering, Stanford University, in JUMBA 2013 held on January 11, 2013.***



★ Taking account of all the above leads us to the next stage of designing and then implement really a new engineering education program's curriculum not only culminating in the major team-based design experience based on the Arinobu design process but also culminating in the self-study or team-based bachelor thesis research experience on appropriate research topics, through the senior year, both by applying the knowledge and skills acquired in earlier course work and those acquired in appropriately related course work in the first semester of the senior year.

★ Remark 9: Most of the engineering education programs of HEIs in Japan have traditionally put dominant emphasis on the full-year bachelor thesis research education in the senior year of their curriculums by applying the knowledge and skills acquired in earlier course work and in appropriately related course work in the first semester of the senior year. In the report produced by the WA's 2005 Review Team for providing a critique of the JABEE system, it was stated that : "Most Japanese engineering education is rooted in applied science. As a result, most Japanese engineering programs emphasize the learning of relevant scientific principles more than the application of those principles in a design context. … ." After the JABEE became a signatory of the WA in 2005, the JABEE has clearly put considerable effort into notifying and engaging with HEIs regarding, in particular, the aspects of design and team work. So, at present, I can say with confidence, it is a time for us, in Japan, to move to the above "next stage of designing and …. ". ///

5. Two front runners causing new waves of engineering education will give us some secrets and suggestions about how to realize our new engineering education involving the Arinobu design process or its substantial equivalence:

- ***✔Olin College of Engineering***
- ***✔College of Engineering and d.school of Stanford University.***

★ ***Prof. James D. Plummer, Dean of Engineering, Stanford University, gave a lecture about "Educating Engineers and Scientists for the 21st century", 15:35 - 16:20, on January 11, in JUMBA 2013 held at Hilton San Francisco Airport Bayfront, on January 11-12, 2013. In his lecture, he pointed out the following important and interesting insights.***

So far, we in HEIs have educated students from the view-point of putting emphasis on:

- ***science based - lots of mathematics, physics, chemistry***
- ***Science and mathematics first, engineering later.***
- ***Focused on preparing students to be "immediately productive" in a corporate environment.***

But, educational environments in HEIs have already changed as follows:

- ***Internet - information anytime, anywhere. Students today go first to the internet for solutions to problems, help with understanding concepts, etc.***
- ***Class notes, lectures, on virtually any topic are widely available on the internet.***
- ***Social networking tools are becoming very useful to students in getting help from experts or other students.***
- ***Careers – global, unpredictable, lifelong learning essential.***
- ***Technology – rapid changes, innovation wins. Practicing engineers don't have the luxury quarter or semester long courses.***

The roles of engineering schools in the 21 century :

- ✔ ***Provide a quality technical education in a way that attract the best and brightest young people to engineering.***
- ✔ ***Teach students how to be entrepreneurial, creative, innovative, to "think out of the box".***
- ✔ ***Create technologies and ideas that can "reinvent" existing companies or spawn new companies.***
- ✔ ***Provide on going professional education easily accessible to working professionals.***

★ ★ ***Engineering schools have focused mainly on the first bullet historically. Now, we need to work on all of them.*** ★ ★

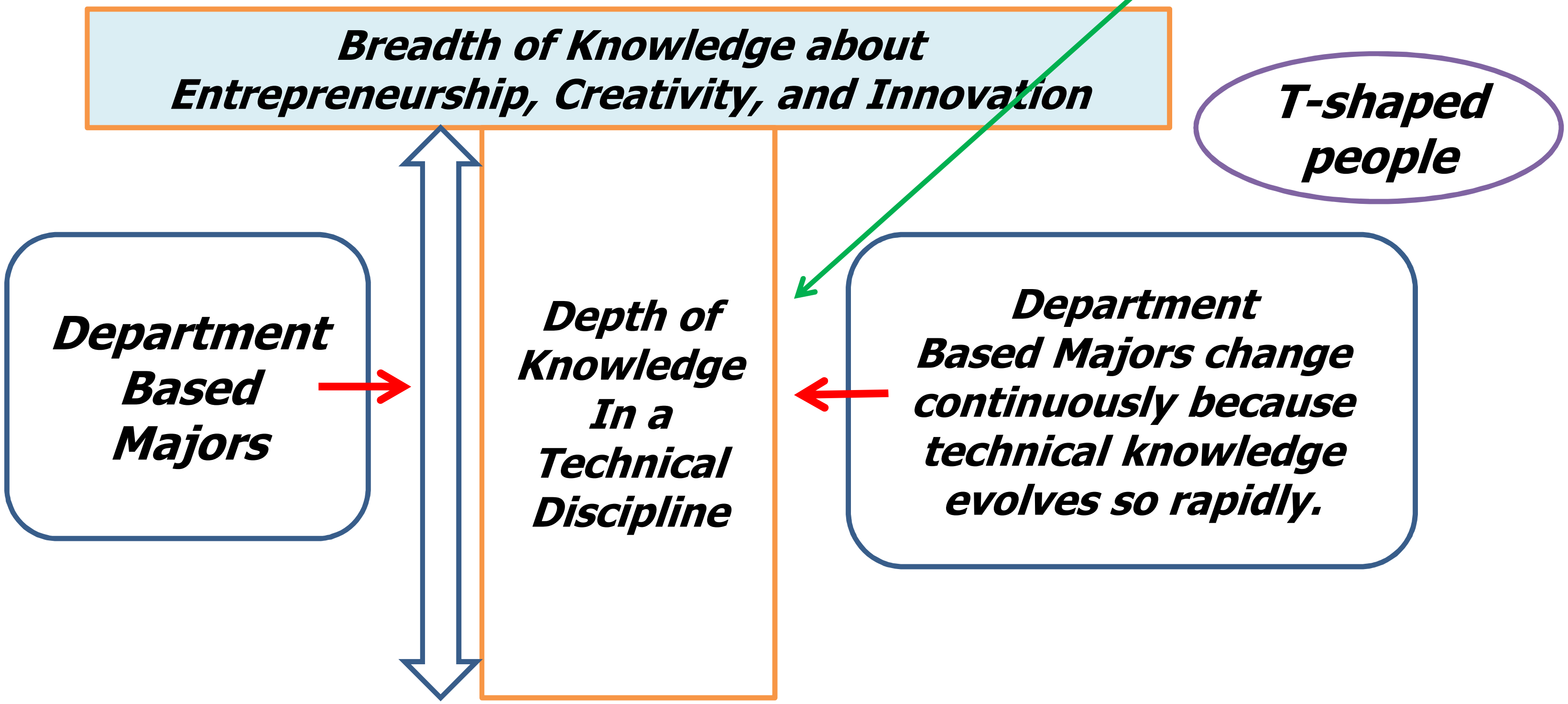
Educating engineers/scientists for the 21 century:

- ✔ ***Reinventing engineering education – how do we get more young people interested?***
- ✔ ***Going beyond technical skills – what else do our students need to know to be successful?***
- ✔ ***Research – what should universities work on to create the next wave of innovation?***
- ✔ ***Online education.***

Educating engineers/scientists for the 21st century

What are the critical skills our students need?

- ✔ Technical depth in a particular field
- ✔ Creativity and innovation
- ✔ Entrepreneurial outlook
- ✔ Communication skills
- ✔ Ability to work well as a member of a diverse team
- ✔ Global knowledge and experience
- ✔ Commitment to life-long learning



What are the critical skills our students need?

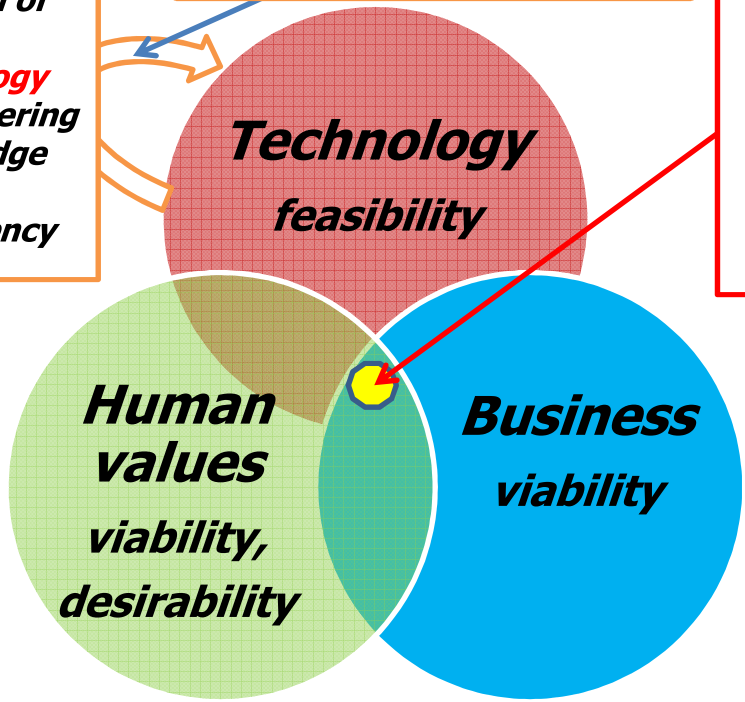
- ✔ Technical depth in a particular field
- ✔ Creativity and innovation
- ✔ Entrepreneurial outlook
- ✔ Communication skills
- ✔ Ability to work well as a member of a diverse team
- ✔ Global knowledge and experience
- ✔ Commitment to life-long learning

You don't teach these skills through normal classroom experiences. And others, …

Design and innovation:
team-based design,
creativity, innovation,
thinking "out of the box",
The best approach is to give students open-ended problems with multiple solutions they haven't seen before.

Creation of new technology by engineering knowledge and competency

In IEA's GA&PC profiles



d.School (Hasso Plattner Institute of Design at Stanford):
Established by David Kelly, in 2005;
7 departments' graduate students can take one of d.school classes (but, no credits) of capacity of about 25 or 40 students;
Faculty: more than 70

★ Remark 10: The d.school bootcamp bootleg is a working document which is very helpful for our design thinking practice. --- An update from 2009 edition.

The d.school is a hub for innovators at Stanford.

The d.school's faculty members provides students with a methodology for innovation that combines creative and analytical approaches, and requires collaboration across disciplines. All of the classes at the d.school are team-taught by a robust mix of faculty and industry leaders, combining disciplines like computer science with political science, and CEOs with elementary school policy-makers.

Students come to the d.school with an intense curiosity, a deep affinity for other people, and desire to gain an understanding beyond their own experience, but can get neither credits nor degrees from the d.school.

Students and faculty in engineering, medicine, business, law, the humanities, sciences, and education find their way at the d.school to take on the world's messy problems together. Along the way, students develop a success for producing creative solutions to even the most complex challenges they tackle.

The process called design thinking at the d.school draws on methods from engineering and design, and combines them with ideas from the arts, tools from the social sciences, and insights from the business world.

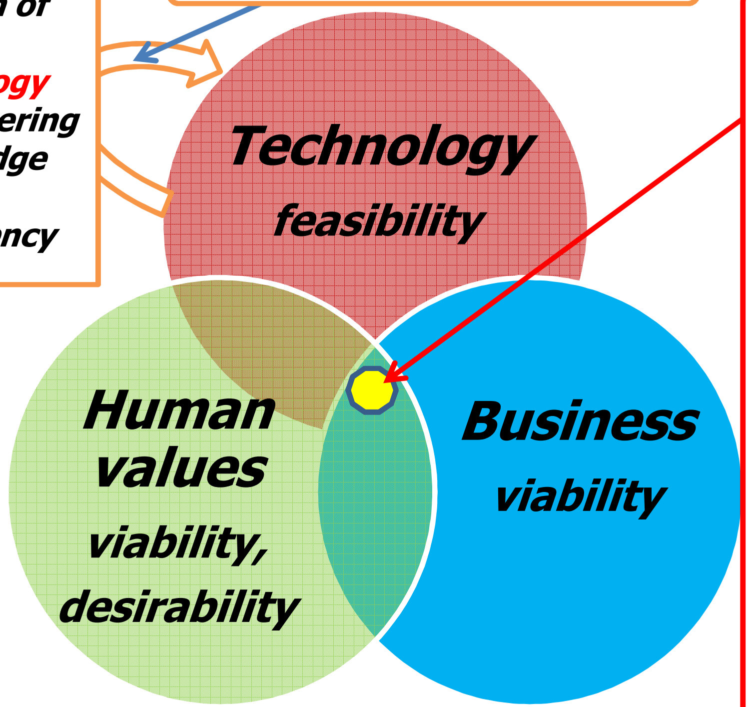
Students learn the design thinking process together, and then personalize it, internationalize it, and apply it to their own challenges. ///

Four visions of d.school [C. Meinel and L. Leifer; 'Design Thinking Research', in "Design Thinking"(edited by H. Plattner, C. Meinel and L. Leifer), Springer-Verlag(2011)]

1. Great innovators and leaders need to be great thinkers.
2. Design thinking is a catalyst for innovation and bring new things into the world.
3. High impact teams work at the intersection of technology, business, and human values.
4. Collaborative communities create dynamic relationship that lead to breakthroughs.

Creation of new technology by engineering knowledge and competency

In IEA's GA&PC profiles



Design and innovation
(team-based design, creativity, innovation, thinking "out of the box")
"imagine it": The challenge – create value from a simple object, post-its.

--- Secrets of how to brush up the ability to design ---
/Real projects
/inter-disciplinary teams
/need-finding first
/fail early and often, but learn from failures

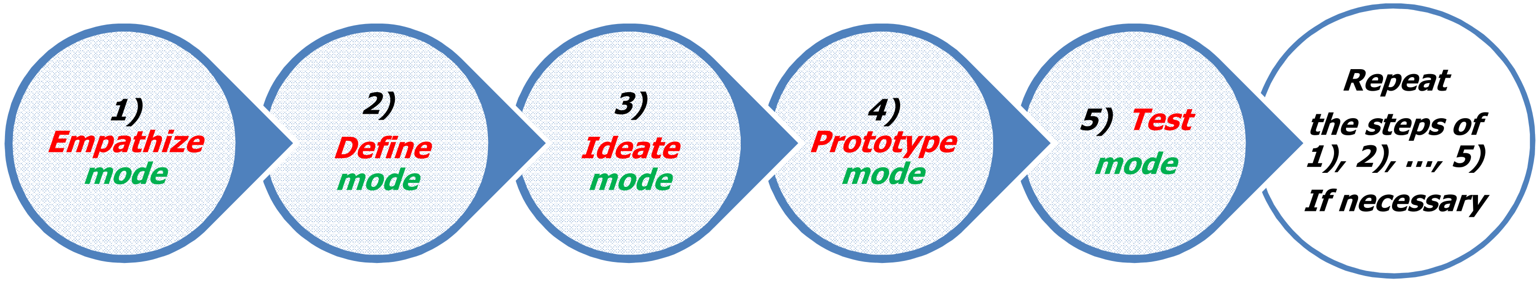
★ ***Seven mindsets of design thinking in the bootleg are described as***

1) Show don't tell (Communicate your vision in an impactful and meaningful way by creating experiences, using illustrative visuals, and telling good stories.);
2) Focus on human values (Empathy for the people you are designing for and feedback from these users is fundamental to good design.);
3) Craft clarity (Produce a coherent vision out of messy problems. Frame it in a way to inspire others and to fuel ideation.);
4) Embrace experimentation (Prototyping is not simply a way to validate your ideal; it is an integral part of your innovation process. We build to think and learn.);
5) Be mindful of process (Know where you are in the design process, what methods to use in that stage, and what your goals are.);
6) Bias toward action (Design thinking is a misnomer about doing that thinking. Bias toward doing and making over thinking and meeting.); and
7) Radical collaboration (Bring together innovators with varied back-grounds and viewpoints. Enable breakthrough insights and solutions to emerge from the diversity.). ///

★ ***Five steps of design thinking in the bootleg are:***

1) Empathize mode;
2) Define mode;
3) Ideate mode;
4) Prototype mode; and
5) Test mode.

The details of these process modes and dozens of the respective specific methods to do design work are explained in the tangible bootleg.



The bootleg includes many secrets and suggestions to be referred in the stage of HEIs' designing and then implementing the respective new engineering education programs in which the process or its essential equivalence of the above six phases, based on the idea of "design for the value (koto)" and "design for the thing (mono) as the realization of the designed value", is built.

Educating engineers/scientists for the 21st century

What are the critical skills our students need?

- ✔ ***Technical depth in a particular field***
- ✔ ***Creativity and innovation***
- ✔ ***Entrepreneurial outlook***
- ✔ ***Communication skills***
- ✔ ***Ability to work well as a member of a diverse team***
- ✔ ***Global knowledge and experience***
- ✔ ***Commitment to life-long learning***

STVP:
Stanford Technology Ventures Programs
http://dtvp.stanford.edu

Entrepreneurship programs are springing up in many universities, sometimes in business schools, sometimes in engineering schools.

- ✔***courses***
- ✔***seminars***
- ✔***student competitions***
- ✔***summer internship in startups***

Remark 11: Entrepreneurship is a mindset, an outlook that shapes the way you see the world and the possibilities that it holds. It is born of a basic dissatisfaction with the status quo, and it is the courage to say to yourself, "This could be better".///

What are the critical skills our students need?

✔ ***Entrepreneurial outlook***

STVP:
Stanford Technology Ventures Programs
http://dtvp.stanford.edu

Sample STVP courses

- ✔ ***Introduction to high technology entrepreneurship***
- ✔ ***Management of technology ventures***
- ✔ ***Global entrepreneurial marketing***
- ✔ ***Strategy venture formation***
- ✔ ***Entrepreneurial thought leader seminar***
- ✔ ***Organizational behavior and management***
- ✔ ***Entrepreneurial finance***
- ✔ ***Creativity and innovation***
- ✔ ***Negotiation***

Does online education challenge traditional residential education?

✔ If residential education is simply sitting in lecture halls taking courses, then the answer may well be Yes.
✔ But, a typical undergraduate residential education is much more than this.
✔ And a PhD education is much more than this.
✔ But, MS degrees based purely on attending classes could be at risk, particularly if top tier universities "certify".
✔ And junior colleges, community colleges could be affected.

Conclusion: Residential programs may have to reinvent themselves to compete with low cost online programs.

Prof. James D. Plummer, Dean of Engineering, Stanford University closed his lecture on "Educating engineers/scientists for the 21 century" by the following concluding words:

The roles of engineering schools in the 21 century are to:
✔ Provide a quality technical education in a way that attract the best and brightest young people to engineering.
✔ Teach students how to be entrepreneurial, creative, innovative, to "think out of the box".
✔ Create technologies and ideas that can "reinvent" existing companies or spawn new companies.
✔ Provide on going professional education easily accessible to working professionals.
★ ★ The world is changing, universities are changing, education is changing. We live in interesting times! ★ ★

and by the following quotation sentences from "Educating Engineers for 2020 and Beyond"(by Charles M. Vest, President Emeritus, MIT; NAE).

"Students are driven by passion, curiosity, engagement and dreams. ."
"In the long run, making universities and engineering schools exciting creative, rigorous, demanding, and empowering milieus, is more important than specifying curricular details".

★ ***Before the d.school, there was an interesting innovative experiment of the Franklin W. Olin College of Engineering, located in Needheim, MA, USA (near Boston), which attracts our attention.***

Dr. Masakazu Sengoku, the executive vice-president of Niigata University and I visited Olin College to know some of its secrets on March 28, 2013.

Olin College was officially opened in Fall 2002 to its inaugural freshman class. In 2012, Olin College was ranked as #6 Best Undergraduate Engineering Programs, non-doctoral in USA (in US News & World Report).

Also, in January, 2013, the Olin College's three founding academic leaders, Richard Miller, David Kerns and Sherra Kerns received one of the engineering's highest honors - the Bernard M. Gordon Prize of $500,000 - from the National Academy of Engineering, with the NAE President Charles M. Vest's words of

"This team of educational innovators has had a profound impact on society by improving the way we educate the next generation of engineers", and "Olin serves as an exemplar for the rest of the engineering world and a collaborative agent for change".

★ ***By the way, in the mid-1990s, the National Science Foundation and the engineering community in USA called for sweeping structural and cultural changes in engineering education, including***

- ***A shift from disciplinary thinking to interdisciplinary approaches;***
- ***Increased development of teaming skills;***
- ***Greater consideration of the social, environmental, business, and political context of engineering;***
- ***Improved student capacity for life-long learning; and***
- ***Emphasis on engineering practice and design throughout the curriculum.***

In 1997, the Franklin W. Olin Foundation enthusiastically responded to the above call, and founded Olin's college through a grant from the Foundation.

In early 1999, the foundation hired the founding president, Richard Miller.

President Miller hired the founding leadership team in the spring of 1999, including David Kerns as Provost, Sherra Kerns as Vice President for Innovation and Research, Stephen Hannabury as Vice President for Administration and Finance, and Duncan Murdoch as Vice President for External Relations and Enrollment.

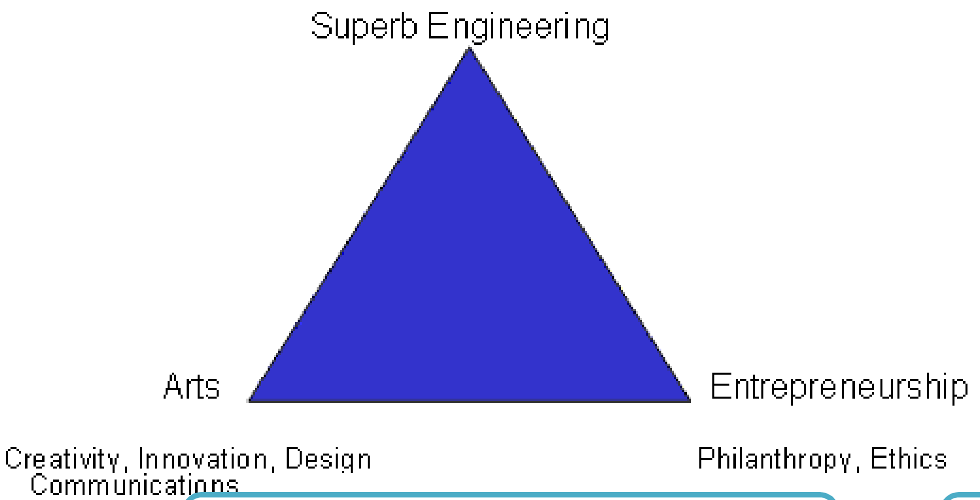
Olin College's first faculty members joined the college by September 2000, and Olin College was conceived to be a college that incorporates the above call and other creative ideas into a new curriculum.

Remark 12: In 1997, the ABET's EC 2000 of "outcomes base – what students learned –" was created as change from the ABET's then rigid engineering criteria of "input base – what material is taught –", in ABET-EAC by taking account of the same call.///

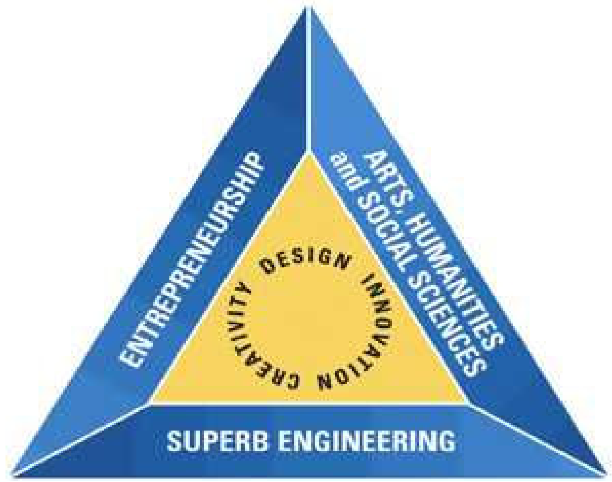
★ *In order for Olin College to create its innovative curriculum, the "Olin Triangle", a combination of superb engineering, arts (creativity, innovation, design, communications) and entrepreneurship (basics in business, ethics and a spirit of philanthropy), was first proposed as a visual expression of Olin's goal to "educate the whole person" and "open doors to student possibilities", as are in the two figures in the slide of page 67.*

The curriculum is based on the "Olin Triangle". There is a deep commitment at all levels to active learning and interdisciplinary courses built around hands-on projects.

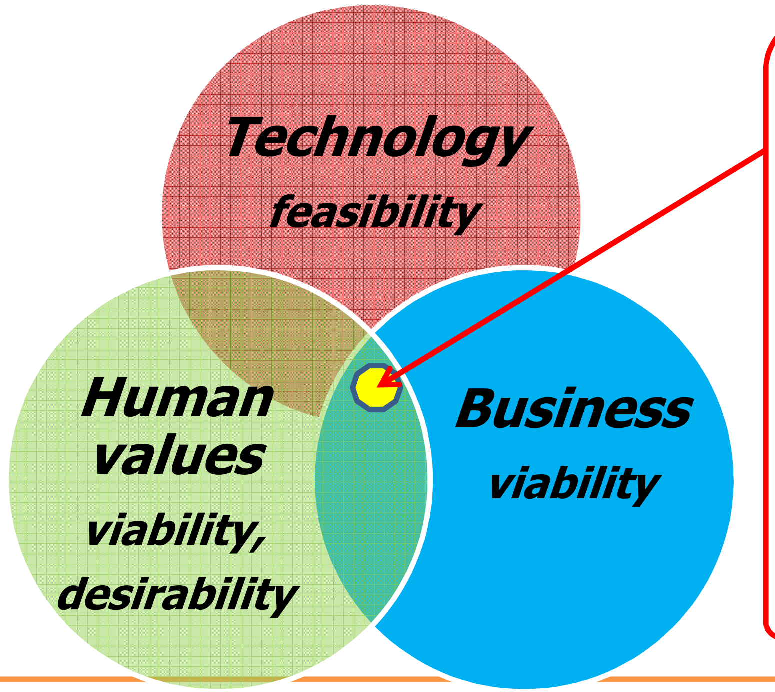
At Olin, learning and doing go together from the start. This real-world approach culminates in SCOPE (Senior Consulting Program for Engineering), a significant, year-long engineering project for an actual client.



The Olin College Curriculum
"Triangle Model"



The Olin Triangle Symbolic Representation
of the triple thread of Olin



Design and innovation
team-based design, creativity, innovation, thinking "out of the box"
may be created in the d.school of Stanford university

This figure is regarded to be substantially equivalent to the contents of the Olin triangle and its symbolic representation.

★ ***The founding principle of Olin College is to prepare leaders able to predict, create and manage the technologies of the future.***

Students, who will become such leaders, must have:

- ***A superb command of engineering fundamentals and specialized knowledge in field of major ;***
- ***A broad perspective regarding the role of engineering in society;***
- ***The creativity to envision new solutions to the world's problems; and***
- ***The entrepreneurial skills to bring their visions into reality.***

The Olin Curriculum addresses these outcomes. Rigorous technical courses and hands-on projects, throughout the curriculum, require students to apply engineering concepts to actual, practical problems.

Interdisciplinary courses and projects make explicit the connections both within the technical world and between engineering and society.

Extensive design experiences, significant work in the arts and humanities, and an emphasis on original expression encourage students to develop and to apply their creativity.

Continuous use of teamwork, communication skills, and entrepreneurial thinking give students the tools they need to take their solutions from the research lab to the world at large.

★ Olin College offers students a wider range of courses in business, natural sciences, social sciences, arts, and humanities through its educational partnerships with Babson College, Wellesley College, and Brandeis University, all of which are located near from Olin College.

★ Olin College's mission is to prepare students to become exemplary innovators who recognize needs, design solution and engage in creative enterprises for the good of the world.

★ Olin College's aspiration is to seek to redefine engineering as a profession of innovation encompassing

1) the consideration of human and societal needs;
2) the creative design of engineering system;
3) the creation of value through entrepreneurial effort and philanthropy.

The college is dedicated to the discovery and development of the most effective educational approaches and aspires to serve as a model for others. (Indeed, this attracted our strong interest of visiting Olin College!)

★ Prof. Lynn Andres Stein, Director of Initiative Innovation in Engineering Education, told us "In the past three years, about 200 universities have visited Olin to benchmark and explore ways of initiating major changes in their own curriculum. Nine other institutions have already made substantial changes that were inspired by the Olin program and dozens of others are considering such changes."

★ For your information about Olin College:

Founded; 1997;
Founding president hired; early 1999;
Officially opened; Fall 2002 to its inaugural freshman class;
School type: private, coed, college;
Academic calendar: semester;
2012-2013 Tuition: $40,475 ;
Students: 344 (Olin College offers only degrees in engineering and provides large merit-based scholarships, which pays for half tuition, to all admitted students.);
Enrolled: 45.64% female / 87%(out of state) / 10.47%(International) ;
Admissions: 16.4% (Average high school GPA: 3.9; A GPA of 4.0 out of 4.0 means that student got all A grades.);
Student-faculty ratio: 9:1;
Accreditation: Olin College was accredited by the regional accreditation board NEASC (the New England Association of School and Colleges) on December 6,2006, and Olin College's degree-granting programs in Electrical and Computer Engineering (ECE), Mechanical Engineering (ME), and Engineering [concentrations: Bioengineering (E:Bio), Computing (E:C), Design (E:D), Materials Science (E:MS), or Systems (E:SYS)] were accredited by ABET-EAC on August 31, 2007;
Curriculum: expires every five years, and must undergo an internal curriculum review;
Key features of Curriculum: Multidisciplinary integration of subjects, hand-on learning, team-oriented projects, open-ended problem-solving, competency-based assessment, feedback-driven improvement, flexible program options;
General distribution requirements: minimum 120 credits/46 credits for engineering/30 credits for Math(≥10) and Science/26 credits for AHS(≥12) and Entrepreneurship;
Faculty: All faculty's members hold five-year renewable contracts with no opportunity to tenure, unlike many HEIs in USA. However, they are all nationally recognized scientists and researchers from top institutions with a deep commitment to undergraduate teaching. ///

★ ***As the results of our visiting at Olin College, we recognized that Olin College was a real front runner caused a new wave of engineering education before the d.school of Stanford university, and we felt that Olin College must give Stanford university's motive for opening its d.school in 2005, because the thought about design of the d.school seems to be the essentially same as the Olin triangle proposed as a visual expression of Olin's goal. The difference is that the d.school serves for graduate students but Olin College serves for undergraduate students.***

We have obtained a lot of information about Olin College and those about the d.school of Stanford University, and we have understood that there are valuable secrets and treasures integrated from experiments and experiences made in the respective institutions. These are no doubt essentially useful for designing a new engineering education program in which the Arinobu design process is built. The program will be expected to foster many of the next generation of ambitious and active engineers, with creative, innovative and/or entrepreneurial minds, who always imagine or draw the "vision for desirable life and society", and conceive the "value" for improving the "richness of people's mind and quality of life," and furthermore design the "value" fulfilling various needs of people and society.

6. Concluding remarks

Before this concluding remarks, I would like to express my sincere thanks to every person that spared no efforts in cooperating with me for gathering information about or preparing this set of slides.

Dr. M. Arinobu wrote his essay entitled "From thing-creation (mono-zukuri, in Japanese) to value-creation (koto-zukuri, in Japanese) -- toward new innovation", in Japanese in the Journal Chemistry and Chemical Industry (November, 2008).

Prof./Dr. M. Sengoku had an opportunity of reading the essay by sheer chance, because the Journal was out of the box of our ordinary reading journals and transactions. He kindly sent its copy to me. The contents of the essay moved me to draft a design process consisting of the above six phases 1)~6). In my today's talk, taking the implication of Arinobu's essay into consideration, I decided to call the process the Arinobu design process (or the Arinobu design model).

On January 21, 2012, I pointed out the importance of the above design process (i.e., the Arinobu design process in my today's talk) by showing its drafting in my talk on "New changes in engineering education in the world" (in Japanese) in the final lecture at Chuo University before my retirement.

For the period of January 11-17,2013, Dr. M. Sengoku and I traveled San Francisco Bay area to gather information about activities and secrets of JUMBA 2013, the d.school of Stanford University and the ITRIS (Center for Information Technology Research in the Interest of Society) of the University of California at Berkeley.

On January 18, 2013, I called attention to the importance of the above design process (i.e., the Arinobu design process in my today's talk) by showing its drafting, again, in my talk on "Some issues on design education to be reformed in engineering education and the challenges of the Stanford University's d.school" (in Japanese) in the JABEE symposium, Tokyo.

For the period of March 27-31, 2013, Dr. M. Sengoku and I traveled Boston area to gather information about some of the secrets of Olin College of Engineering and those of MIT Media Lab.

All of the above led me to give such a plenary talk about "New waves of engineering education and IEA's graduate attributes", in this 28th ITC-CSCC (Yeosu, Korea, on July 1, 2013), just today. After mentioning the expected effects of the Queen Elizabeth Prize for Engineering, the recent meaning of engineering and WA's signatories' respective correspondences to the WA exemplar (i.e., the WA's GA profile with the WA's Knowledge profile), I explained the details of the Arinobu design process (or the Arinobu design model), which are built in a new wave of engineering education with its program curriculum that incorporates design and research projects in the student's experience starting from the freshman year and culminating in a senior design project and a senior research project. The senior design project requires the students to undertake a team-based design that

enriches their knowledge and skills in practical aspects of engineering principles and methodologies of the Arinobu design process and the senior research project requires the students to undertake a self-study or team-based research that enriches their knowledge and skills in research, investigation, development and/or experiment through problem-solving of not-yet-solved problems, and developing or discovering of new theories or theorems, new methods, new algorithms, new technologies, new materials, and new properties, and through rare experience of making real creative addition to human knowledge by finding a new scientific phenomenon or property by chance in the process of experiment or observation.

Next, I introduced the Olin College of Engineering which is a front runner of causing a new wave in engineering education Bachelor-degree granting program of four years, and the Stanford University's d.school which is another front runner of causing a new wave in (non-degree project-based) graduate education on various kinds of design, because the valuable secrets and treasures integrated from experiments and experiences made in the respective institutions are essentially helpful for us to realize any new engineering education involving the Arinobu design process or its substantial equivalence. At present, I can say with confidence, it is a time for several engineering schools in HEIs in Japan to move to the challenge of realizing the new engineering education involving the Arinobu design process. Of more importance is that the right of the challenge is open to any engineering school of HEIs in WA's signatories that wants to attract

and get as many of the best and brightest young students with passion, curiosity, engagement and dreams as possible, and to foster as many graduates as possible of engineering education programs of the engineering school who can become a next generation of ambitious and active engineers with challenging minds of full of curiosity and with creative, innovative and/or entrepreneurial minds, who always imagine or draw the "vision for desirable life and society", and conceive the "value" for improving the "richness of people's mind and quality of life," and furthermore design the "value" fulfilling various needs of people and society.

The reason why I prepared such a set of many power-point slides is that those who want to know, after this conference, can understand the information and ideas contained in the set of slides by reading thoroughly and make use of the information and ideas for designing and implementing the new sweeping structural and cultural changes appropriate to the respective engineering education programs, as one of international front-runners of engineering education towards 2020 and beyond.

Many of these graduates are also expected to go to graduate schools in order to brush up the critical skills they need (such as listed in the slide of 54) as well as to deepen and/or widen the related underpinning knowledge they need to do so, learning and doing, towards their becoming a next generation of engineers, entrepreneurs, scientists, or professors in the future.

Questions and Discussion

Flowers in my house garden

Thank you

Shoji Shinoda shinoda@m.ieice.org
Waseda University, Ookubo, Shinjyuku-ku, Tokyo

Masakazu Sengoku sengoku@ie.niigata-u.ac.jp
Niigata University, Ikarashi, Nishi-ku, Niigata

Dr. Shoji Shinoda's short biography

A recipient of RCA David Sarnoff Scholarships, 1962-1963 and 1963-1964 in Japan
A Professor, 1982(Apr.)-2012(Mar.), and a Professor Emeritus of Chuo University, 2012(Apr.) ---

He has contributed not only to graph/network theoretical researches on flow/tension networks, electrical circuits, and mobile communication systems (including multi-hop wireless networks), but also to education on circuits, networks and systems. He is a recipient of three Best Paper Awards in 1992, 1997 and 1998, Achievement Award in 2005, and Distinguished Achievement and Contributions Award in 2007, all from the IEICE (Institute of Electronics, Information and Communications Engineers), Japan, and also a recipient of Best Paper Award in 1996 from the 1995 IEEE International Conference on Neural Networks and Signal Processing. He is also a recipient of IEEE Third Millennium Medal in 2000.

He authored or co-authored more than 200 research papers and several handbooks' articles in the above research fields, and several books such as "Graph Theory with Exercises" (Corona Publishing Co., Tokyo) in 1983, "Introductory Circuit Theory" (Volumes (1) and (2)) (Corona Publishing Co., Tokyo) in 1996, and "Linear Algebra" (Corona Publishing Co., Tokyo) in 1997.

He served as a Director of the International Center, 1991(Apr.)-1994 (Mar.), a Dean of the Graduate School of Science and Engineering, 1995 (Nov.)-1999(Oct.), and a University Councilor, 1991(Apr.)-2001(Mar.) and 2002(Apr.)-2011(Mar.), all in Chuo University. Also, he served as the President of JSST (Japan Society of Simulation Technology), 2003(Jun.)-2005 (Jun). He served as the Editor-in-Chief of the Journal of the IEICE, a member of the IEICE Board of Directors (in charge of all publications, except the handbooks and the textbooks, from the IEICE), 2002(May)-2008(May), and the Chair of the IEICE Accreditation Policy Council, 2006(May)-2011(May). He has been the Chair of the IEICE Technical Committee on History of Technology since 2002. In addition, he was a member of the Board of Directors of the JABEE (Japan Accreditation Board of Engineering Education), 2007(June)-2011(June).///