

Role of ChE and ChErs in the 21st century civilization: conceptual understanding of macroeconomic connections embedded in ChE discipline as related to the central theme (paradigm) of the 21st century civilization

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Abstract

Chemical engineering (ChE) was conceived at the close of the 19th century as a new discipline which was designed to support then the newly-emerging industries, oil and petrochemical, by supplying the competent engineers equipped with the pertinent engineering fundamentals and skills. It helped the said industries meet the various demands and ramifications of the new pattern of the human civilization spurred by the advent of automobile transportation at the turn of the 20th century. Now ChE once again is ready to fulfill its societal responsibility as probably the most important discipline and profession in sustaining the 21st century human civilization providing the needed engineers (ChErs) and technologies. In this study, it is attempted to analyze the role of ChE and ChErs in this context, focusing on the macroeconomic connections embedded in the discipline that allow us to envision the big pictures of the 21st century civilization where the well-being of the mankind invariably hinges on five essential industries, *i.e.*, medical, pharmaceutical, energy, environment and materials. It can be argued that ChE is the only discipline that can encompass simultaneously all those five industries indispensable to sustain the 21st century human civilization that can be termed the era of “enjoy-healthy-living-longer”. It is also believed that the historical mission ChE and ChErs are supposed to fulfill now is even bigger than that they took on a hundred years ago and subsequently accomplished with remarkable success in food, clothing, shelter and entertainment industries introducing various technological innovations. The macroeconomic viewpoints are called upon in this study as were in the 2006 article (Hyun, 2006) but focusing on ChE and ChErs this time to view the connections embedded in ChE as the essential components in understanding the historical nature of the role and responsibility of ChE and ChErs. The new paradigm for ChE is also pondered over together with the frequently-cited technology concepts such as IT, BT, NT, ET and ST which are regarded intimately germane to the characteristics and perspectives of the 21st century civilization.

Keywords : chemical engineering, enjoy-healthy-living-longer era, macroeconomic connections, paradigm for ChE, sustainability and human well-being, the 21st century civilization

1. A brief history of ChE genesis

Chemical engineering started in 1888 when the first ChE curriculum was first introduced by Lewis M. Norton at MIT combining together features of mechanical engineering with those of industrial chemistry (Hougen, 1977). The motive was of course provided by the oil and petrochemical industries that were in desperate need of competent engineers capable of handling various challenges at the plant sites and laboratories as well which were not adequately met by either mechanical engineers or industrial chemists. The American Institute of Chemical Engineers

(AIChE) was formed in 1908, and the inauguration of the first separate department bearing the ChE name with Warren K. Lewis as head took place at MIT in 1920. It turns out that a rather long period of time was needed for both the first ChE department and the first ChE society to come into being owing to the not-so-smooth-relationships with chemists some of whom opposed the idea of the newly-formed ChE as a separate discipline and profession. The same thing happened at the British theater, where Institute of Chemical Engineers (IChemE) finally came to light in 1922.

The first comprehensive textbook on ChE came out from MIT with the most apt title “Principles of Chemical Engineering” in 1923 by Lewis, Walker and McAdams, quantifying unit operations and providing the tools for analy-

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zing chemical processes. A host of textbooks followed thereafter by MIT faculty: Elements of Fractional Distillation by Robinson (1922), Heat Transmission by McAdams (1933), Absorption and Extraction by Sherwood (1937), Thermodynamics for ChErs by Weber (1939) and Applied Mathematics in ChE by Sherwood and Reed (1939).

Once the ChE got on the track as a newly-organized discipline and profession, the subsequent path was rather an anti-climax which witnessed the continuation of highly commendable accomplishments on both academic and industrial fronts. Delving into the further details of the history of ChE is thus not pursued in this article while an evolutionary aspect of the development of ChE technology and industry will be presented later.

2. The paradigms for ChE

Now, let's think about an important concept called "the paradigms for ChE". It's an important subject in both academia and industry alike because of the fact that all the advances in ChE discipline and profession during the last hundred years can be summarized around the paradigms. But more importantly, the paradigm concept is deemed paramount in understanding the evolutionary nature of the contributions being made by ChE and ChErs to the human civilization in the 21st century.

2.1. The first paradigm for ChE

As can be seen obvious from the above brief history of ChE genesis, the first paradigm for ChE can be most appropriately described by "Unit process and unit operation" expounded by the first textbook "Principles of chemical engineering" in 1923. Instead of dealing with various, different sub-industries individually, *e.g.*, acid/base, food, paint, textile, petrochemicals, pharmaceutical industries, *etc.* in the purview of ChE, the unifying concept of unit operations and unit processes, *e.g.*, distillation, extraction, reaction, absorptions, *etc.* was introduced as a new principle and a new paradigm around which ChE processes and industries were defined, developed and optimized.

2.2. The second paradigm for ChE

The second paradigm for ChE was presented by the epoch-making textbook titled "Transport Phenomena" authored by Bird, Stewart and Lightfoot, published in 1960. Instead of various unit operations by which ChE had been hitherto studied, the unifying concept of transport phenomena based on mathematics, physics, mechanics and chemistry, *i.e.*, heat, mass and momentum transfer, was introduced to refocus on the underlying principles in the various ChE processes and operations. The impact of these then the most far-reaching principles of transport phenomena was felt not only in ChE but also in other science and engineering disciplines so that the contributions made

by ChE and ChErs to the civilization were interpreted just as meaningful and indispensable as other significant scientific endeavors were.

2.3. The third paradigm for ChE in the 21st century

While the above two paradigms for ChE are rather easy to understand because they are what ChErs mostly concur, the paradigm for the 21st century has not yet been presented as an agreed-upon conclusion. So the present author would like to present the one of his own herewith: the one that can be regarded most apt and closely associated with the concept of the 21st century human civilization: "Sustainability and human well-being". This paradigm has been reached as a conclusion by the author, contemplating the nature of the contributions made by ChE and ChErs to the 21st century civilization. Instead of various transport phenomena and/or various unit operations around which ChE has been defined during the past hundred years, the unifying concept of sustainability and human well-being as the survival and life enhancement issue in the 21st century civilization embedded in the technology concepts such as IT, BT, NT, ET, ST, *etc.* is considered the most relevant paradigm around which ChE and ChErs are poised to make most significant contributions to the 21st century civilization (National research council, 1988; American chemical society, 1996; Grant, 2005).

3. Technology concepts of IT, BT, NT, ET and ST

Clarification of the technology concepts explained here as related to the new paradigm of "Sustainability and human well-being" for ChE in the 21st century civilization is now in order. Categorizing the technology concepts into the three groups with the detailed descriptions as shown in

Technology concepts: IT (Information technology), BT (Biotechnology), NT (Nanotechnology), EET (Energy and environment technologies), SST (Safety and security technologies)

BT, IT

A natural evolution and conclusion for the 21st century civilization, *i.e.*, *enjoy-healthy-living-longer*, requires 5 important industries to sustain the civilization, *i.e.*, medical, pharmaceutical, energy, environment, and materials industries.

NT

A new *methodology* based on small (atomic) scales (macro-meso-micro-nano), *i.e.*, a natural evolution of ChE knowledge

EET, SST

The *first priority*, the overall philosophy and the basic necessities needed for the *survival* of the civilization

Slide 1. Technology concepts: IT (Information technology), BT (Biotechnology), NT (Nanotechnology), EET (Energy and environment technologies), SST (Safety and security technologies).

Slide 1 can be beneficial for an easier understanding of the paradigm. The first group of IT and BT is considered a natural evolution and conclusion for the 21st century civilization, which can be termed as the era for “enjoy-healthy-living-longer” where five important industries are deemed essential to sustain the civilization. Why the present author chose the “enjoy-healthy-living-longer” as theme for the 21st century civilization will be made clear later in this article when the evolutionary aspect of the development of ChE industries in the last hundred years is analyzed and interpreted. The second group of NT is of course a new methodology based on the atomic scale, *i.e.*, a result of the natural evolution of the accumulation process of ChE knowledge. The third group of ET and ST or more aptly EET (energy and environment technologies) and SST (safety and security technologies), are nothing more than the first priority, the overall philosophy, and the basic necessities needed for the survival of the human civilization in the 21st century.

4. AIChE’s definition of ChE profession

“ChE is the profession in which knowledge of mathematics, chemistry, and other natural sciences gained by study, experience, and practice is applied with judgment to develop economic ways of using materials and energy for the benefits of mankind.”

In the above definition written on the official AIChE Website, the keywords are *knowledge, economic ways and benefits of mankind*.

4.1. A simpler definition of ChE profession

Reading the AIChE’s definition of ChE profession, it becomes quite natural to ask the following question: “Can there be a simpler definition of ChE for easier and more practical understanding?” The answer to this question is of course “yes”: ChE is defined and exists to support chemical industries. The key word here is “*support*”. How does ChE, then, support the chemical industries? Basically, in two ways: It provides the chemical industries with two indispensable things: (1) Competent chemical engineers, and (2) competitive ChE technologies. The keywords here are “*competent*” and “*competitive*”.

4.2. Chemical engineers

First, competent ChErs are produced by ChE departments in universities through the process of education and research. The keywords here are “*competent ChErs, and education and research*”.

4.3. ChE technologies

Second, competitive ChE technologies are produced from various disciplines including ChE following through the pathways of perception, conception and birth of the

particular technology, applying management ideas. The keywords here are: “*competitive ChE technologies, various disciplines, and applying management ideas*”.

In other words, technologies emerge from engineering when proper management ideas are applied. Mission-oriented technologies like automobile technology, for instance, can come into being when assorted, required engineering and other knowledge are put together through the management process. (Here management means “get things done through people” according to Peter Drucker.) Next, the concept of industry is to be discussed.

4.4. Chemical industries

Now we pose the question: “What are chemical industries?” First, industries are a macroeconomic entity producing added-value, *i.e.*, GDP, in the national economy for the benefits of the human civilization. These added-value-producing industries are not necessarily manufacturing ones but rather encompass many diverse industries such as banking, hospital, tourism, music or movie industry, *etc.*, as long as they produce added-value. Industries can emerge when microeconomic ideas are applied to the technologies which have been created from engineering and other knowledge applying management ideas as explained in the above: the optimization ideas, *i.e.*, maximization of utility or profits and minimization of costs. The keywords here are “*microeconomic ideas, optimization, maximization of utility or profits, and minimization of costs*”.

Then, the ChE industries can be said to be those that use the ChE technologies (and principles) in producing the added-value.

4.5. National economy

Finally, we think of the national economy in this sequential thought process of connecting engineering, technology, industry and the national economy. After a particular, profitable industry like ChE industry emerges, the next thing required is that this industry should be able to produce added-value, or equivalently contribute GDP to the national economy. Here, needed are macroeconomic ideas to steer this ChE industry in the constantly-evolving macroeconomic environment of the 21st century toward the goal of added-value production. The keywords here: “*added-value, macroeconomic ideas, steer toward the added-value production*”.

Now that a brief history of ChE genesis, the paradigms for ChE, and the concepts of technology, industry, and the national economy have been studied as related to ChE and ChErs, next ChE and ChErs for the 21st century is to be summarized.

5. ChE for the 21st century

An evaluation of the current situation where ChE finds

Current situation of ChE

Positive side:

1. The only discipline that can *simultaneously encompass the five key industries* required to sustain the 21st century human civilization.
2. The *highest starting salary* for ChE college graduates in U.S.
3. The U.S. has been, is, and will be the *leader in ChE discipline and profession* in the world. (Historically, a trade-surplus sector in U.S.)

Negative side:

No major predominant industry now yet but rather many small, and supporting ones after the oil and petrochemical industries have relinquished the dominant roles in ChE field.

Conclusion:

1. The above negative assessment is of *short-term nature*.
2. The *long-term prospects are quite bright* with the key five industries to continue to *rely on ChE and ChErs* for guidance, innovation and breakthroughs in the 21st century civilization.

Slide 2. Current situation of ChE.

itself is presented in Slide 2. The positive side cites several points stemming from the impeccable status ChE has established for itself during the 20th century in both U.S. and the world. First, thanks to the enviable track record as a most productive and successful discipline and profession, the ChE college graduates in the U.S. have been enjoying the highest starting salaries on all degree levels for several decades, which is considered to continue throughout the 21st century barring any totally unexpected, detrimental things that might happen in the civilization.

Second, as explained in this article so far, ChE is considered the only discipline that can simultaneously encompass the five essential industries required to sustain the 21st century human civilization. This is of course due to the fact that the five industries, *i.e.*, medical, pharmaceutical, energy, environment and materials, which at first glance appear to defy efforts to find any common thread among them, but seen through the historical perspectives the commonality of coherent theme looks quite evident. These industries are all futuristic in the sense that they are indispensable to sustain the 21st century human civilization than any other and they are most pertinent to the central theme of the century, *i.e.*, era for enjoy-healthy-living-longer. ChE is then positioned conspicuously in the center of this theme being most relevant to all those five industries: While energy and environment are considered to be the core part of the ChE profession, medical and pharmaceutical industries are increasingly involved in the core curricula of ChE with BT and NT principles. The materials industries are the fronts where ChErs historically excel in their creative innovations bringing out new materials and new solutions.

Of course, there is a negative side to ChE in the 21st century, albeit quite minor. After the oil and petrochemical industries have relinquished their dominant role in the ChE fields lately in terms of employment, R&D support, and general identification and affiliation, there are major industries yet to come forward to completely fill this gap for

Historical mission for ChE and ChErs

Continue to make the most meaningful and significant contributions to the 21st century human civilization as was in the 20th century by playing the leadership roles (not just leading roles) as a responsible profession /discipline, and knowledgeable, credible societal leaders.

Slide 3. Historical mission for ChE and ChErs.

ChE. This negative assessment of ChE is, however, of short-term nature, and the long-term prospect for ChE is quite bright, since the above-mentioned five industries continue to rely on ChE and ChErs for guidance, innovation, and breakthroughs.

6. Historical mission for ChE and ChErs:

In line with the bright future for ChE and ChErs in the 21st century civilization, the general, historical mission statement is presented in Slide 3: Continue to make the most meaningful contributions to the 21st century human civilization as was in the 20th century by playing the leadership roles (not just leading roles) as a responsible profession and discipline, and knowledgeable, credible societal leaders.

6.1. Salient contributions made by ChE and ChErs during the 20th century: Examples

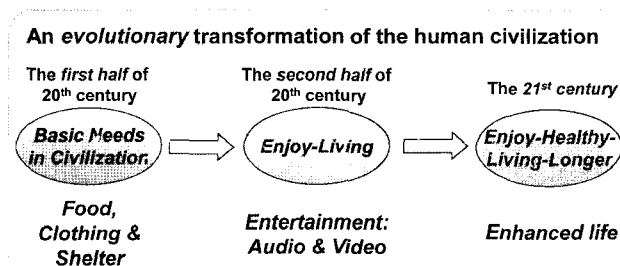
Before presenting the summary of the 20th and 21st century civilization as viewed from ChE perspectives, Slide 4 lists some salient examples of the tremendous contributions made by ChE during 20th century. Fertilizer industry for making a quantum jump in food production, synthetic fibers for clothing, and various new materials notably

Contributions made by ChE during the 20th century: Examples

- (1) **Fertilizers industry for food production, synthetic fibers for clothing, and various new materials including plastics and ceramics for shelters in the first half of the 20th century.**
- (2) **Cell-phone batteries for audio and flat panel display for video to name just two examples that ChE contributed in the entertainment era of the second half of the 20th century.**

Slide 4. Contributions made by ChE during the 20th century: Examples.

A summary of the 20th/21st century civilization



Slide 5. A summary of the 20th/21st century civilization.

including plastics for shelters and living are examples of the ChE contributions in the first half of the 20th century. Cell-phone batteries for audio and flat panel display for video can be named as just two examples of the ChE contributions in the entertainment era of the second half of the 20th century

6.2. Summary of the 20th/21st century civilization

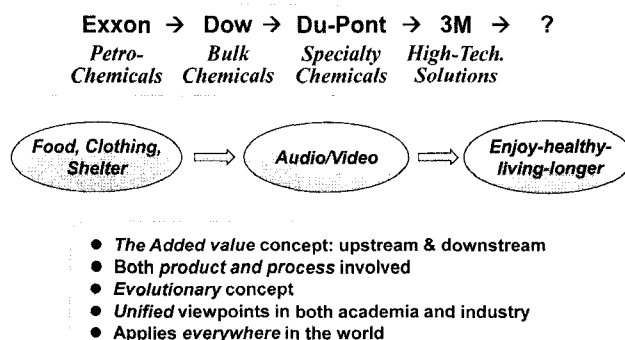
Based on all these findings, Slide 5 presents a summary of the 20th and 21st century civilization with dominant concepts for each period: The fundamental changes in the civilization along the different time horizons in the 20th and 21st centuries have been highlighted in the slide, quite evident from the viewpoints of evolutionary transformation in human civilization. In a nutshell, the first half of the 20th century witnessed the basic needs in civilization, *i.e.*, food, clothing and shelter, to be satisfied at least in the developed world, while in the second half the enjoy-living theme came along as a natural aspiration of the civilization following after the basic necessities satisfied, with the entertainment spearheaded by audio and video dominating the landscape of the civilization. The 21st century is now witnessing another evolution of the civilization transformation, *i.e.*, aspiration to enjoy living longer with health. This enhanced life simply warrants the backup of the five essential industries mentioned above where ChE and ChErs can perform an outstanding job better than any other human endeavors in technologies or industries. Next, an example of a model for illustrating the evolutions of chemical industry having gone through both 20th and 21st centuries is presented in Slide 6.

7. Evolution of ChE

7.1. An evolutionary development model for the chemical industry viewed from civilization standpoints

In order to facilitate understanding of the concepts lying in the evolution process the names of well-known, global oil and chemical companies representing the industry have

An evolutionary development model for the chemical industry



Slide 6. An evolutionary development model for the chemical industry.

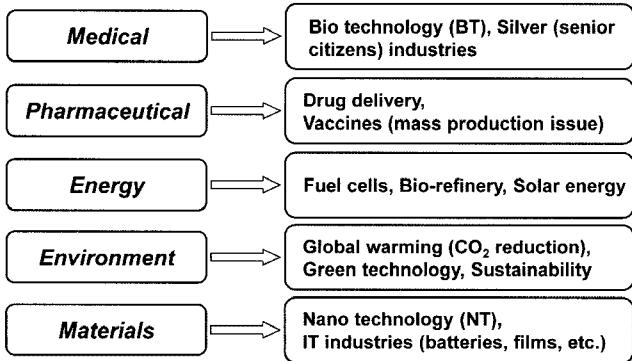
been used in Slide 6. (They are not restricted, however, to the particular stages indicated in the slide, but rather considered to constantly engage in other stages as well because in the 21st century global markets they simply can't afford to dwell on single stage only.)

Starting with petrochemicals and then going on to bulk and specialty chemicals, the chemical industry in these days posits to provide so-called high-tech solutions. Here, the terminology of "solutions" is being used in a wider sense that the industry meets the societal demands providing the answer in the form of solutions, not just the narrowly defined products.

This evolutionary model for the chemical industry based on the well-known upstream-downstream process structure in ChE, *i.e.*, a traditional concept characteristic to oil and petrochemical industries, also sits well with the notion of added-value production discussed earlier in this article: The direction from upstream to downstream processes exactly coincides with that of increasing added-value production. In other words, the development of the chemical industry has been made following this upstream-downstream, evolutionary pathway because it is the same direction of increasing added-value, which also increases the marginal product of capital investment as defined in macroeconomics.

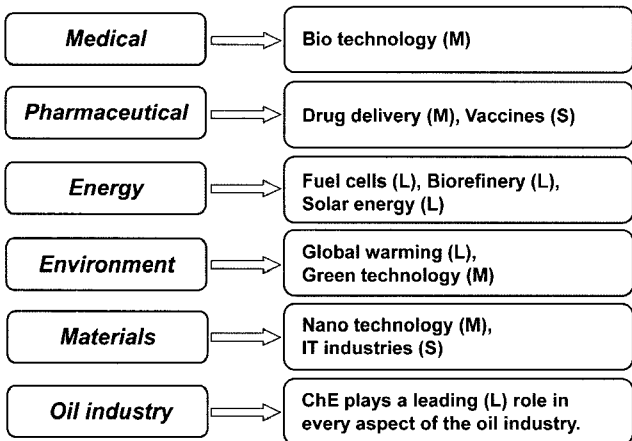
The fact that the evolutionary development model for the chemical industry illustrated in Slide 6 represents the unifying viewpoint in both industry and academia and also applies everywhere in the world, then clearly suggests how the chemical industry will shape its future development: By following the same direction of increasing added-value and increasing marginal product of capital (including human capital) investment. It thus doesn't require much imagination to understand why BT, *i.e.*, biotechnology, plays an increasingly more important role in the 21st century ChE industries. It is simply because in many ChE technologies and industries BT is getting more responsible

Examples of new technologies in the five industries (1)



Slide 7. Examples of new technologies in the five industries (1).

Examples of new technologies in the five industries (2)



Slide 8. Examples of new technologies in the five industries (2).

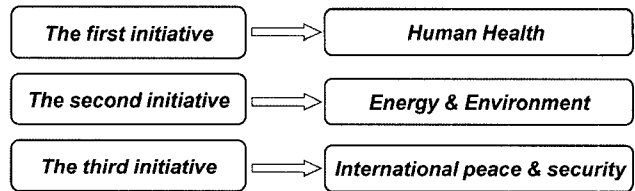
for the production of added-value.

Next, we proceed to explain further about the five industries sustaining the 21st century civilization as mentioned in this article, focusing attention this time on how ChE and ChEs play their role in them.

7.2. Example processes and products in the five essential industries for the 21st century civilization

Examples of the processes and products in those five industries are listed in Slide 7, while they are further labeled in Slide 8 according as ChE plays a leading(L), supporting(S) or mid-level role(M) in them. (By leading role, it is meant that ChE calls the shots and control the market, and by supporting role, ChE receives the order and no control on the market. By mid-level role, ChE is supposed to partially participate in the decision-making.) As anticipated, most processes in the energy category have been identified as ChE playing a leading role, whereas other industries have processes where ChE plays either mid-level or supporting role. For a comparison purpose, oil

Stanford University Challenge for the 21st century



❖ *Three agendas of the 21st century civilization.*

❖ *Stanford University's strengths:*

- *Geopolitical position* in the northern California (both domestic and international advantages)
- *Strong support* from alumni & world-renowned faculty
- *Entrepreneurial heritage*

Slide 9. Stanford University Challenge for the 21st century.

industry was added in Slide 8 to those five industries, to exhibit the fact that ChE plays a leading role in every aspect of that industry. The noteworthy point in Slide 8 is that ChE plays an important role in all the five industries essential for sustaining the 21st century civilization, whether it is leading, supporting or mid-level roles. In other words, ChE is indeed a common thread connecting through all those five industries so that ChE is deemed indispensable in the 21st century civilization.

Next, an interesting case of Stanford University is shown in Slide 9 where an ambitious five-year, fund-raising program of \$4.3 billion has been announced in 2006 with three initiatives for which the funds will be allocated and used to enable the university to meet the 21st century challenges in a rather grand style.

8. University's role

8.1. Stanford university's challenge for the 21st century

The three initiatives Stanford University has chosen are shown in Slide 9, *i.e.*, human health, energy and environment, and international peace and security. It is immediately clear that ChE plays a central role in all three initiatives: In the energy and environment initiative no explanation is necessary, and in the human health initiative it has been readily seen in recent years that ChE plays an increasingly popular role in medical and pharmaceutical industries for fusing the engineering ideas with the medical needs. As for the international peace and security initiative, ChE's role in oil technology, business and policy amply explains the relevancy of ChE in this initiative, too.

It should also be pointed out here that the above three initiatives are actually the same as the three commonly-cited agendas of the 21st century civilization. They are simply enumerated here emphasizing Stanford University's strengths in a rather dramatic fashion, being wrapped around the

University education

Broaden the horizon of ChE education so that the new ChE graduates can adequately perform with renewed competence and responsibility to play an indispensable role as societal leaders in the knowledge-technology-oriented 21st century civilization.

Slide 10. University education.

initiatives. Of course, the strengths Stanford University can boast are: Geopolitical position in the northern California, as both domestic and international advantages, and the unparalleled entrepreneurial heritage coupled with strong alumni support and world-renowned faculty.

8.2. The leadership concept at university

Now let's turn to the education issues at universities which are considered to be of paramount importance for ChE and ChErs to successfully carry out their historical mission in the 21st century civilization as stipulated earlier. In the present author's opinion, there are basically two important concepts at university regarding the education: The one is the leadership and the other is creative thinking. As Slide 10 shows, the foremost the university education should implement in the 21st century is to broaden the horizon of (ChE) education so that the new (ChE) graduates can adequately play with renewed competence and responsibility an indispensable role as societal leaders in the knowledge-technology-oriented 21st century civilization.

In Slide 11, the outline of the leadership concept as required on the university level is described. The most important notion within the leadership concept is how to let the students develop the ability to see, think, and evolve

The Leadership concept

- **Although it encompasses a wide range of thoughts, one of the most important, definitely indispensable aspects of the leadership concept is the ability to see, think and evolve the big pictures of the civilization.**
- **To able to do the big pictures as a leader requires the understanding of the human civilization (the big C-word), i.e., the 21st century civilization.**
- **The objective and goal of the ChE leader is thus make significant and meaningful contributions to the 21st century civilization.**

Slide 11. The leadership concept.

the big pictures of the civilization. Although the leadership concept encompasses a wide range of thoughts, one of the most important, definitely indispensable aspects of the leadership concept is this ability to be thoroughly understood by the would-be national and international leaders. The first step toward the big pictures requires the understanding of the human civilization (the big C-word), i.e., the 21st century civilization, which in turn requires the whole range of subjects to be thoroughly studied at university, including but not limited to, the following: History, macroeconomics, philosophy, technology, industry, etc. Thus, on the part of ChE leaders-to-be, thorough understanding of the above subjects at university can't be emphasized too much. The leadership concept should be "instilled" in the ChE graduates so that they can competently handle the agendas of the 21st century civilization being played out in the era of enjoy-healthy-living-longer. (ChE has been preoccupied with distillation too long, and it's about time to give equal time and attention to "instill" and "distill" from now on.)

8.3. The creative thinking at university

Regarding the second notion at university education, i.e., the creative thinking, the present author just wants to emphasize one thing here: At university, students should never pursue the questions that seek "the" answer simply because those questions work against the creative thinking and thus cannot be important: Questions like "what is the definition of the second thermodynamics law?", or "what is the name of the economist often called "the father of macroeconomics" belong to that group. Instead, questions like "what industries will likely grow faster than others in next five years for ChErs?", or "explain how the GDP can be increased next year above 7%" are deemed more important because they are less subject to memorization of "the" answer per se but rather more germane to "remembering the underlying principles through understanding".

An old joke about a retiring professor, who was asked about how he could manage to get away with asking the same questions every year at the exams and then responded saying "I change the answers" is not a joke, but rather a story of a good professor to be commended for his efforts to foster the creative thinking in the students. "Your answers are as good as mine, because there simply are not "the" answers." The most important lesson to be learned from this "joke" is the fact that every year the exam question is the same and already known to everybody, but nobody knows the answer. The reason for this is that the exam answer is always changing and cannot be known a priori to anybody including the professor.

8.4. Research at university

In the above, it's been explained why the two concepts of leadership and creative thinking are so important at uni-

versity education. Now the other side of the coin called university, *i.e.*, research, is to be discussed. Actually education and research at university are complementary to each other in the sense that it's meaningless to think one without the other at university. This is especially so when it comes to the issue of rearing leaders at university for the society. In other words, education is necessarily enriched in terms of its direction, relevancy and knowledge content by the ongoing research conducted at university whereas research is justified by the fact that universities raise competent and responsible societal leaders who in turn make contributions to the civilization. In order to understand clearly the research performed by university, the two contrasting R&D concepts are considered now, *i.e.*, academic R&D and industrial R&D, because the former mostly means research at university.

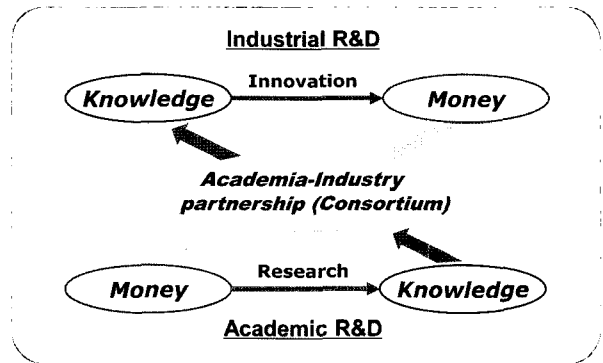
8.5. Academic R&D versus industrial R&D

Just as education and research at university are complementary to each other, academic R&D and industrial R&D are so, too, as explained below. In other words, they are different from and similar to each other simultaneously. First, the academic R&D, or what we might call research at university, has the characteristics of "Principles or fundamentals are given while applicable processes are sought after," whereas the industrial R&D has the opposite characteristics of "Processes are given while explaining principles are sought after."

Second, the academic and industrial R&D's both can be called transformations: Academic R&D, or just simply research, is the transformation of money into knowledge while industrial R&D is the transformation of knowledge into money. While it is rather straightforward to understand that university research, or academic R&D, produces knowledge (including the university graduates) using money, the notion that the industrial R&D generates money from knowledge (including the university graduates) is also readily understood remembering the definition of industry made earlier in this article as producing added-value in the national macroeconomy. The transformation of knowledge into money performed by industrial R&D is also called "innovation."

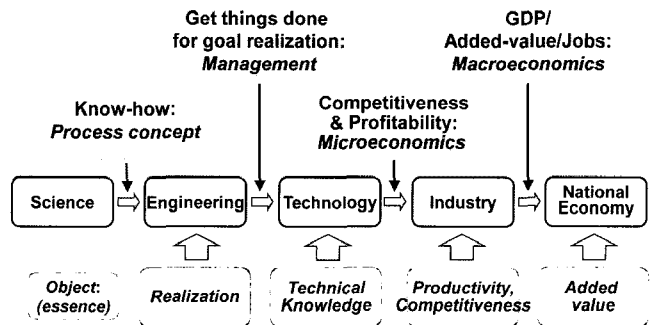
Slide 12 illustrates the two said transformations called university research and industrial innovation. Then it is readily evident that these two transformations can be and should be connected because the same two entities are involved, knowledge and money, albeit in the reverse directions. This connection actually has been traditionally established in human civilization through the general concept of the academia-industry partnership (consortium). The knowledge (including the university graduates) is transferred from university to industry while money from industry to university. This is of course for the mutual benefits of academia and industry but more importantly for

Interdependence of academia and industry through research and innovation



Slide 12. Interdependence of academia and industry through research and innovation.

Sequential process connecting the concepts of science, engineering, technology, industry and the national economy



* Jae Chun Hyun, *Korea-Australia Rheology Journal*, 18, 31-38 (2006)

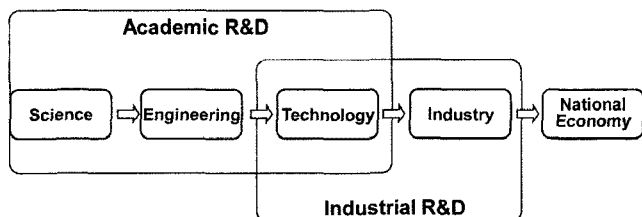
Slide 13. Sequential process connecting the concepts of science, engineering, technology, industry and the national economy.

everybody's benefits in the national economy.

Next, summarizing the results explained earlier in this article connecting the various macroeconomic entities between science and the national economy through engineering, technology and industry, Slide 13 illustrates such sequential process. It clearly shows how essential management, microeconomic and macroeconomic ideas are in connecting various macroeconomic entities. It also exhibits what the key objects (essence) are involved in each entity, *i.e.*, realization, technical knowledge, competitiveness and added value, for engineering, technology, industry and national economy, respectively.

Once we have the sequential picture leading to the national economy as in Slide 13, it can also be utilized to explain further the academic and Industrial R&D's. Slide 14 shows the graphical explanation of the two concepts, *i.e.*, the purviews of the academic and industrial R&D's. The key point in this picture is that both academic and

Academic R&D versus industrial R&D



Slide 14. Academic R&D versus industrial R&D.

Goals for ChE departments at university

- ChE departments should prepare the *education program* emphasizing *leadership and creative thinking* concepts in accordance with the mission.
- *University research, i.e., academic R&D, transforming money into knowledge*, should be solidly based on sound academic-industry partnership concept which also promotes *industrial R&D, i.e., innovations, transforming knowledge into money (added-value)*.
- University should maintain the *education environment conducive to the mission*.
- The *AIChE* should play the leading role in *summoning talents and strengths* from the top ChE departments to prepare ChE for the 21st century.
- The top ChE departments in the U.S. should make concerted efforts towards the *successful implementation of this new mission*.

Slide 15. Goals for ChE departments at university.

industrial R&D's share the common technology whose object (essence) is of course the (technical) knowledge as shown in Slide 13, *i.e.*, technology plays the connecting role for the two R&D's.

8.6. The goals for ChE departments

Now that all the concepts have been explained in the article, it appears appropriate at this juncture to consider the goals for the particular department at university, *i.e.*, ChE departments, as to how the departments should be run in line with the mission statements for ChE and ChErS shown in Slide 3. The goals for the ChE departments, especially the top ones in the world, are summarized in Slide 15.

As for university education, the two fundamental concepts *i.e.*, leadership and creative thinking, should be emphasized in the education program prepared in accordance with the mission. The university research, or R&D, should be solidly based on sound philosophy of academia-industry partnership programs through which both knowledge and money are readily transferred between academia and industry for everybody's benefits. The education environment should also be maintained in accordance with and conducive to the mission.

The top ChE departments in the world, especially the ones in the U.S. where ChE has been, is and will be playing the leadership role for the whole world, should make concerted efforts towards the successful implementation of the mission. AIChE should also, as the ChErS' oldest and largest technical society in the world, play the leader's role in summoning required talents and strengths from the top ChE departments to prepare ChE for the 21st century, where ChE and ChErS are bound to excel others in making most meaningful contributions to the human civilization, in the era of "enjoy-healthy-living-longer".

Finally, two more items are included here to make this article complete with pertinent information on ChE and ChErS. The first is about the whole industries including ChE ones, *i.e.*, Dow 30, the list of 30 largest companies listed on New York Stock Exchange representing the

Dow 30 industrial companies

MARKETS & STOCKS > DOW 30 Components

• Reference: CNN Money April 28, 2008

- ChE: 9
- EE: 7
- ▲ ME: 4
- △ Financial: 5
- Consumer: 5
- Misc.: 1

Dow 30 components			
Company	Price	Company	Price
3M Co. ●	77.82	Intel Corp. ● ○	22.56
Alcoa Inc. □	35.72	IBM ○	123.08
American Express Co. △	47.77	Johnson & Johnson ●	67.31
AIG Inc. △	47.53	JP Morgan & Chase & Co. △	47.79
AT&T Inc. ○	38.58	McDonald's Corp. ■	59.67
Bank of America Corp. △	38.30	Merck & Co Inc. ●	40.72
Boeing Co. ▲	84.84	Microsoft Corp. ○	29.83
Caterpillar Inc. ▲	82.25	Pfizer Inc. ●	20.43
Chevron Corp. ●	92.69	The Coca-Cola Co. ■	59.33
Citigroup Inc. △	26.60	The Home Depot Inc. ■	29.78
Dupont Co. ●	49.88	The Procter & Gamble Co. ●	66.55
Exxon Mobile Corp. ●	92.46	United Technologies Corp. ▲	72.68
General Electric Co. ○	33.33	Verizon Communications ○	37.04
General Motors Corp. ▲	21.38	Wall-Mart Stores Inc. ■	57.65
Hewlett-Packard Co. ○	47.45	Walt Disney Co. ■	32.36

Slide 16. Dow 30 industrial companies.

Starting salaries for college graduates in U.S.

FROM DEGREES TO DOLLARS

Here are some average starting salaries for the class of 2007

* REFERENCE: CNN Money April 5, 2007

MAJOR	AVG. STARTING OFFER	Vs. 2006
Chemical engineering	\$59,707	+5.6%
Electrical engineering	\$54,915	+1.6%
Mechanical engineering	\$54,695	+5.7%
Computer Science	\$52,177	+2.5%
Civil engineering	\$47,750	+4.8%
Accounting	\$47,421	+2.7%
Business administration	\$44,048	+7.5%
Marketing	\$41,285	+10.3%
Liberal arts	\$31,333	+1.2%

* SOURCE: NATIONAL ASSOCIATION OF COLLEGES AND EMPLOYERS

Slide 17. Starting salaries for college graduates in U.S.

entirety of industries. Slide 16 lists those 30 companies with their stock prices on April 28, 2008, where the present author also classified them according as their main businesses are ChE, ME, EE, financial, consumer or miscellaneous. It is noteworthy to notice that ChE companies outnumber other industries (total nine out of 30 are ChE companies), a sign that ChE industries represent the main portion of the national economy.

The second piece of information is included in Slide 17 where the starting salaries for college graduates of various disciplines as of April, 2007 are listed with ChErs on the top. As a matter of fact, ChErs have been on the top for several decades, another sign that the service of ChErs is appreciated greatly by the civilization.

9. Concluding remarks

A systematic analysis of ChE and a comprehensive approach to the synthesis of the new ChE discipline and profession which makes meaningful and significant contributions to the 21st century human civilization have been undertaken. Various concepts have been introduced to explain the role of ChE and ChErs in the 21st century: paradigms for ChE, the technology concepts like IT, BT, NT, EET, and SST, the definition of ChE profession, the concepts of ChErs, ChE technologies, and ChE industries, the historical mission for ChE and ChErs, summary of the 20th/21st century civilization, an evolutionary development model for ChE industry, the five essential industries sustaining the 21st century civilization, Stanford University's challenge for the 21st century, the three initiatives by Stan-

ford University, the leadership and creative thinking concepts at university, academic R&D (university research) and industrial R&D (innovations), the goals for ChE departments. In a nutshell, the good news is that the future of ChE and ChErs is extremely bright in the 21st century in the sense that the new era of enjoy-healthy-living-longer is bound to rely on ChE and ChErs for guidance, innovation and breakthroughs.

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