Renaissance scientists and engineers:
Mass, energy and informations

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Abstract
To cope with the complex economical, societal, science and engineering challenges in the new era, it is proposed to promote the spirit of renaissance scientists and engineers, as well as the spirit of open mind, and the inspiration of innovative ideas. The definition and characters of renaissance scientists and engineers are given. Renaissance scientists and engineers are those not only understand Why and How Things work but also on Why and How the World works. The importance of horizontal and vertical integration, as well as the relationship among mass, energy and information are discussed.

Key words
global challenges, renaissance scientists and engineers, mass, energy and information, vertical and horizontal integration

1. Renaissance and renaissance scientists

The Renaissance was a cultural movement that spanned the period roughly from the 14th to the 17th century, beginning in Italy in the Late Middle Ages and later spreading to the rest of Europe (Wikipedia, 2013).

The 14th century saw the beginning of the cultural movement of the Renaissance. The rediscovery of ancient texts was accelerated after the Fall of Constantinople, in 1453, when many Byzantine scholars had to seek refuge in the West, particularly Italy. Also, the invention of printing was to have great effect on European society: the facilitated dissemination of the printed word democratized learning and allowed a faster propagation of new ideas. During the Renaissance, great advances occurred in geography, astronomy, chemistry, physics, mathematics, manufacturing, and engineering. But, at least in its initial period, some see the Renaissance as one of scientific backwardness. Historians like George Sarton and

Figure 1: David, by Michelangelo (Academia gallery, Florence), an example of high renaissance art

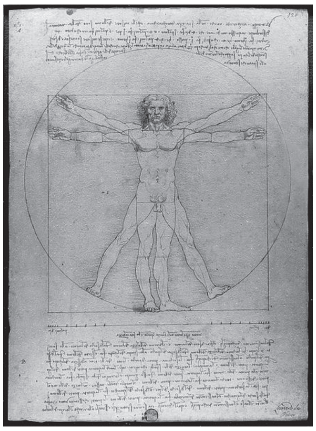

Figure 2: Leonardo da Vinci's Vitruvian Man, an example of the blend of art and science during the renaissance

Lynn Thorndike have criticized how the Renaissance affected science, arguing that progress was slowed for some amount of time. Humanists favored human-centered subjects like politics and history over study of natural philosophy or applied mathematics. Others have focused on the positive influence of the Renaissance, pointing to factors like the rediscovery of lost or obscure texts and the increased emphasis on the study of language and the correct reading of texts. Marie Boas Hall coined the term Scientific Renaissance to designate the early phase of the Scientific Revolution, 1450-1630. More recently, Peter Dear has argued for a two-phase model of early modern science: a Scientific Renaissance of the 15th and 16th centuries, focused on the restoration of the natural knowledge of the ancients; and a Scientific Revolution of the 17th century, when scientists shifted from recovery to innovation. Figure 1 shows an example of high renaissance art, and Figure 2 shows an example of the blend of art and science during renaissance.

Many fascinating people have been engineers or have an engineering background. Engineers are not just researchers, designers, and inventors. They are also artists, astronauts, Olympians, heads of states, and even Academy Award recipients.

2. Engineering the changing worlds

The latest that has sounded in the first decade of this new century is global integration with its realities and challenges. We are engaging a world that is connected multi-dimensionally – a global system of systems. The world's business and public sector leaders of today and tomorrow need to be equipped to cope with a rapid escalation of systems-level diversity and complexity that confront them, an unprecedented level of such complexity expected indeed to accelerate in the coming years within the global environment. The scope of vertical integration and horizontal integration and the need of ability to work well as a member of a diverse team are shown in Figure 3 and Figure 4 respectively. Figure 5 shows the models of basic and applied research, and Figure 6 shows the interaction among discoveries and inventions (Narayanamuri et al., 2013).

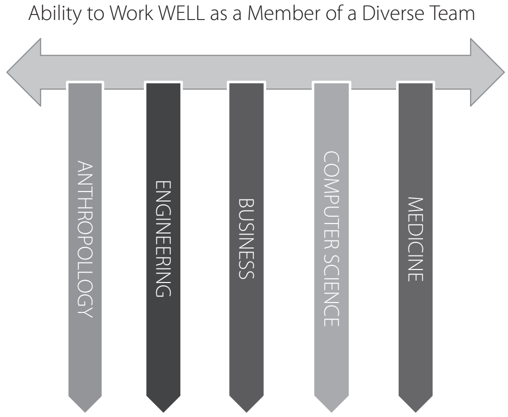

Figure 4: The need of ability to work well as a member of a diverse team

3. Economical, science and engineering challenges

The world is currently still recovering from the effects of the 2008-2009 global recessions. As these effects continue to be felt, many unresolved economic issues add to the uncertainty associated with the long-term assessment of world economic markets. Currently, there is wide variation in the economic performance of different countries and regions around the world. Among the more mature OECD (Organization for Economic Co-operation and Development regions), the pace of growth varies but generally is slow in comparison with the emerging economies of the non-OECD regions. In the United States and Europe, short- and long-term debt issues remain largely unresolved and are key sources of uncertainty for future growth. Economic recovery in the United States has been weaker than the recoveries from past recessions, although expansion is continuing. In contrast, many European countries fell back into recession in 2012, and the regions economic performance has continued to lag. Japan, whose economy had been sluggish before the devastating earthquake in March 2011, is recovering from its third recession in 3 years. In contrast to the OECD nations, developing non-OECD economies, particularly in non-OECD Asia, have led the global recovery from the 2008-2009 recessions. China and India have been among the world's fastest growing economies for the past two decades. From 1990 to 2010, China's economy grew by an average of 10.4 percent per year and India's by 6.4 percent per year. Although economic growth in the two countries remained strong through the global recession, both slowed in 2012 to rates much lower than analysts had predicted at the start of the year. In 2012, real GDP in China increased by 7.2 percent, its lowest annual growth rate in 20 years. India's real GDP growth slowed to 5.5 percent in 2012.The world's real gross domestic product (GDP, expressed in purchasing power parity terms) rises by an average of 3.6 percent per year from 2010 to 2040. The fastest

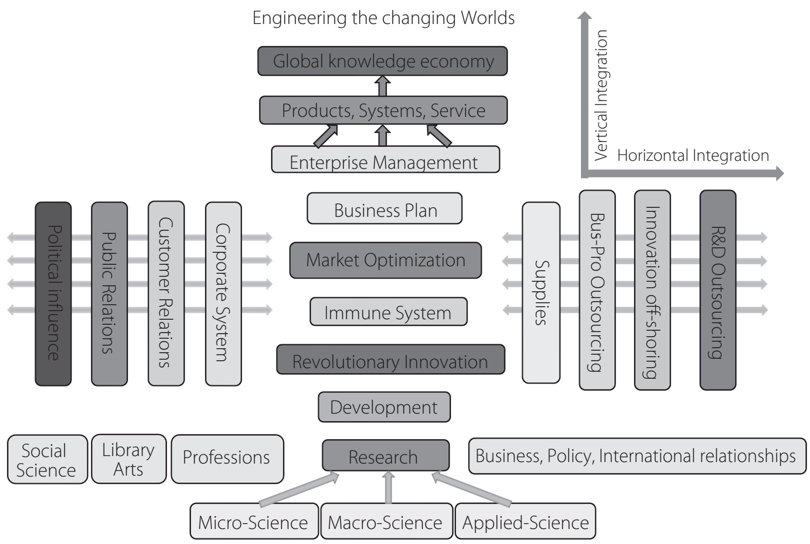

Figure 3: The scope of vertical integration and horizontal integration (The millennium project, University of Michigan)

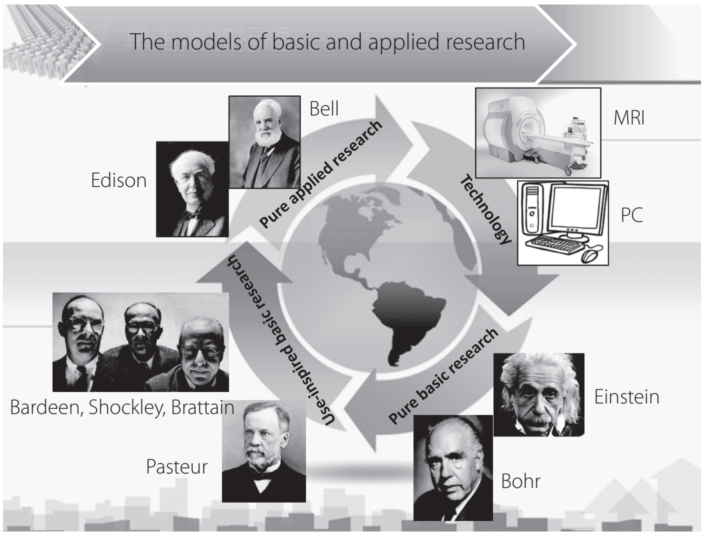

Figure 5: The models of basic and applied research

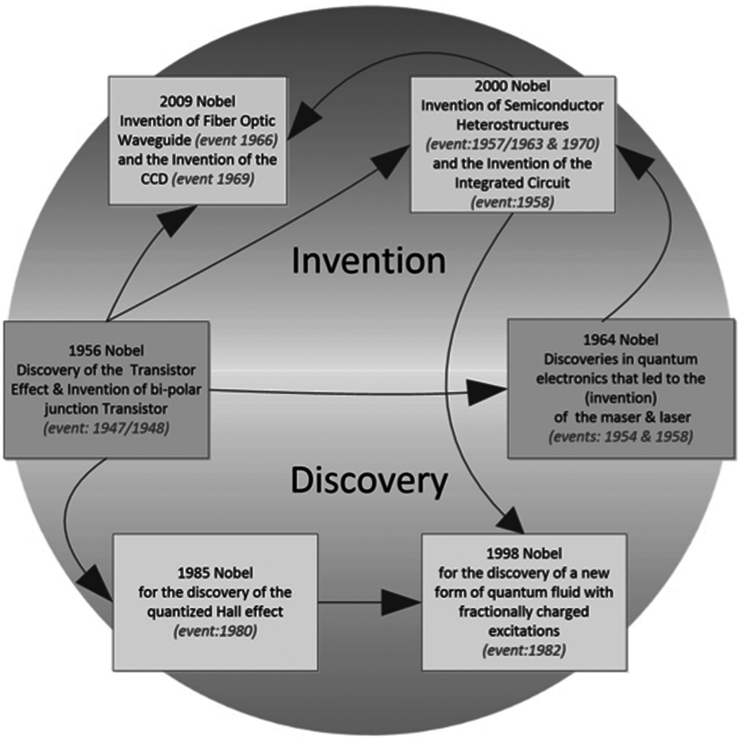

Figure 6: The interaction among discoveries and inventions (Narayanamurti et al.,)

rates of growth are projected for the emerging, non-OECD regions, where combined GDP increases by 4.7 percent per year. In the OECD regions, GDP grows at a much slower rate of 2.1 percent per year over the projection, owing to more mature economies and slow or declining population growth trends. The strong growth in non- OECD GDP drives the fast-paced growth in future energy consumption projected for these nations (U.S. Energy Information Administration, 2013).

Along with the above economical challenges, the global trends and societal challenges are shown in Figure 7 and Figure 8 respectively. While Figure 9 shows major challenges in science and engineering

4. Renaissance scientists and engineers

To cope with the current unprecedented complex challenges in economics, society, science and engineering, the author proposes to promote the spirit of renaissance scientists and engineers, as well as the spirit of open mind, and the inspiration of innovative idea. As Prof. Dennis Gabor, Nobel Physics Laureate 1971, pointed out : "The future cannot be

Figure 7: The global trends

Figure 8: The societal challengers

predicted, but futures can be invented". What are renaissance scientists and engineers? Renaissance scientists and engineers are those not only understand Why and How Things work but also on Why and How the World works. The characters of renaissance scientists and engineers can be summarized as follows:

- Global thinking instead of local thinking;
- Circle thinking instead of linear thinking;
- Closed loop thinking instead of open loop thinking;
- Life cycle thinking instead of partial life thinking;
- Three "R" thinking (Reduce, Re-use, Recycle).

It would also be useful to understand the essence of science, engineering, invention, innovation and entrepreneurship as follows:

- Science: Discovery
- Engineering: Creation
- Invention: Realization of Ideas
- Innovation: Successful of Implementation of New Things
- Entrepreneurship: Value Creation

Science is answering Why, and Engineering is answering How. Engineering plays a vital role in how to implement the global sustainable development. Therefore it is essential to attract young talent students to pursue engineering courses. The Technical University of Denmark (DTU) has implemented CDIO (Conceive, Design, Implement, Operation) reform to engineering education, which builds a better, stronger and more motivating and rewarding way for students and educators to undertake curricular and extra-curricular activities in modern engineering education. Its important key elements are engineering authenticity in curricular activities and a large degree of event-oriented projects that offers profiling opportunities for engineering students and educators (Crawley et al., 2007). Figure 10 shows the interaction among conceive, design, implement and operation.

5. Mass, energy and information

Along with the spirit of renaissance scientists and engineers, it is foremost importance of the study on the correlation between energy and information in redirecting our way to sustainable development. The proposed correlation between energy and information is a fundamental principle that we should pay more attention, particularly in the current big data age. The understanding of the correlation between energy and information will promote both the sustainable energy and sustainable information. The author has proposed that the correlation between information and energy can be expressed by (1), where Σ^I are various Information, Σ^E are various Energy (Chan and Jian, 2013a; 2013b).

$$\Sigma^I \Leftrightarrow \Sigma^E \qquad (1)$$

The above expression (1) provides only general guidelines for integrating energy and information. It would be further exciting to research on the relationship among mass, energy and information.

Frank Wilczek (2004), Nobel Physics Laureate 2004 said: "Perhaps the most dramatic result is that we fulfill the promise of Einstein's "second law" $m = E/c^2$ (his first law being $E = mc^2$). That is, we explain how most of the mass of matter comes from energy".

In 2003 J. D. Bekenstein claimed that a growing trend in physics was to define the physical world as being made of information itself (Bekenstein, 2003). Examples of this include the phenomenon of quantum entanglement where particles can interact without reference to their separation or the speed of light. Information itself cannot travel faster than light even if the information is transmitted indirectly. This

Figure 9: Major challenges in science and engineering
Source: National Academy of Engineering, U.S.A.

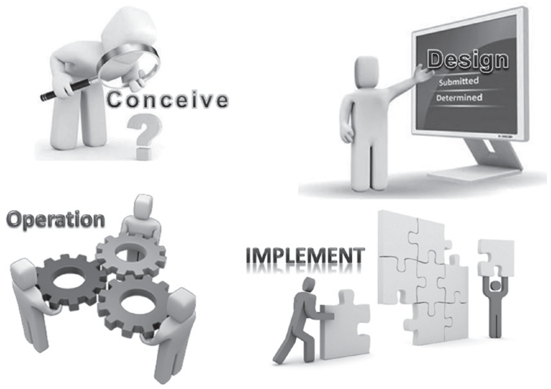

Figure 10: Innovative engineering education approach; conceive, design, operation and implement

could lead to the fact that all attempts at physically observing a particle with an "entangled" relationship to another are slowed down, even though the particles are not connected in any other way other than by the information they carry.

It is noted that Maxwell's demon has haunted thermodynamics for well over a century (Radhakrishnamurty, 2010), since James Clerk Maxwell first suggested that a small demon might be able to selectively allow only hot atoms through a small gate, gradually extracting heat from a gas without expending much in the way of energy. But there's no such thing as a free lunch, and the demon feeds on information: it needs to know which atoms are hot. Eventually, it was recognized that information was being exchanged for energy, and equivalence between the two was calculated based on theoretical considerations. It was early work demonstrated by the Maxwell's demon thought experiment in 1867, where in this experiment, a direct relationship between information and another physical property, entropy, is demonstrated. A consequence is that it is impossible to destroy information without increasing the entropy of a system. In practical terms this often means generating heat. Another, more philosophical outcome is that information could be thought of as interchangeable with energy. Thus, in the study of logic gates, the theoretical lower bound of thermal energy released by an AND gate is higher than for the NOT gate (because information is destroyed in an AND gate and simply converted in a NOT gate). Physical information is of particular importance in the theory of quantum computers.

A team of scientists in Tokyo has recently made a real-world demon. In 2010, Maxwell's demon was experimentally verified by several Japanese scholars. It demonstrates that the information on the motion of a nano scale polystyrene bead in a bath of buffer solution can indeed be converted to its potential energy (Toyabe et al., 2010). We should take this into account when we formulate the model of the correlation between information and energy.

Japanese experiment shows us a generalized second thermodynamics law as:

$$\langle \Delta F - W \rangle \leqq k_B T I \quad (2)$$

ΔF: Free Energy difference between states
W: Work done on the system
k_B: Boltzmann constant

T: Environment Temperature

I: The manual information content obtained by measurements

It is interesting to note the work of L. Szilárd (1929), where he associated the entropy decrease with the information access and developed a model which later be improved by Rolf Launder (1961) that one bit of information in the system equivalent to $k_B T$ ln2, and he thought the entropy that Demon earned from controlling the gate would be reduced in this way. But from the Japanese experiment and Bennett`s paper in 1987 (Bennett, 1987), we can see, in fact, Maxwell`s demon can abandon or restore the information and demon`s memory was limited, if demon abandon any information, it means, the entropy of the system will be increased. When demon`s memory is full, finally it will start deleting information, in this way, the entropy of the system is increased. Nevertheless we should still consider the Szilárd`s work and thus we can express the correlation between information and energy in more intuitive and complete way as the following, in line with the spirit and characters of renaissance scientists and engineers in global, circle and closed loop thinking:

$$\{\langle \Delta F - W \rangle / 1bit\} \leqq k_B T \ln 2 \quad (3)$$

ΔF: Free Energy difference between states

W: Work done on the system

k_B: Boltzmann constant

T: Environment Temperature

As the author pointed out, a closed loop thinking is one of the characters of renaissance scientists and engineers. Therefore the author proposed the above expression (3) that would give us correct, complete and logic conclusion.

In summary, with the inspiration of renaissance scientists and engineers, the author has proposed that the relationship among mass, energy and information can be integrated as the following: most of the mass of matter comes from energy, while energy comes from information.

6. Conclusion

While we are currently facing the unprecedented complex challenges in economic, society, science and engineering, we should carry forward the spirit of renaissance, open mind and innovation. Renaissance scientists and engineers are those not only understand Why and How Things work but also on Why and How the World works. The characters of renaissance scientists and engineers can be summarized as 1. Global thinking instead of local thinking; 2. Circle thinking instead of linear thinking; 3. Closed loop thinking instead of open loop thinking; 4. Life cycle thinking instead of partial life thinking; and 5. Three "R" thinking (Reduce, Re-use, Recycle). In short, we should have all round universe perspectives. With this in mind, it is importance to research the relationship among mass, energy and information. Where in general, mass of matter comes from energy, while energy comes from information. Therefore two basic equations are proposed, namely $m = E / c^2$ by Einstein, denotes mass comes from energy, and $\{\langle \Delta F - W \rangle / 1bit\} \leqq k_B T \ln 2$, proposed by the author, denotes energy comes from information.

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