Applying Connection and Interaction to Promote Knowledge Creation Capability in Engineering Education

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ABSTRACT: In the knowledge-based society, the teaching and learning in engineering education facing important pedagogical challenges, how to apply the new methodologies, such as interactive strategies, connectionism and so on to help individuals create their own networked knowledge. However, in the current university education system, especially the engineering field which we paid close attention in the past 20 years, it is lack of the effective education methodology which can promote the knowledge creation capability of the students. Applying connection and interaction, a new dimension of teaching and learning, can and should take into account of curriculum changes, perform as innovative or reform actions in teaching practice. This paper aims to introduce a new education paradigm by applying connection and interaction methodology in the engineering education, which is expected as a solution.

In this paper, we focus on introducing some new educational concept and approach, such as from textbook centric to problem centric, the connection of knowledge, and the interaction of knowledge, and integrate them into a course named “Methodology of Knowledge Creation”. The course adopted several models such as SECI model, Small World model, which aims to explore how the connection of knowledge is established, how the interaction of knowledge is performing. In this paper, we also introduced some cases to show the emergence of pattern in the connection of networked technology and market, how to connect different space, how to create shortcuts to the subject frontier. The qualitative evaluations by students are exhibited in the final part.

This practical attempt shows that the education paradigm we introduced has some practical implications for the engineering educator in university.

KEYWORDS: Connection, Interaction, Engineering Education

1. INTRODUCATION

Globalization is an obsessively recurring word in every type of discourse which tries to describe and explain social, economic and political developments in the world today [1]. In the past few decades, globalization processes have induced major changes - economic, technological, cultural, educational, environmental and political.

In the education field, due to the rapid advancement of information and communication technology, students are exposed to mountainous information unprecedentedly. The generation and exploitation of knowledge from information is the predominant factor in the creation of wealth [2].The transformation towards the knowledge society is driven by complex interactions between technical, social, economic, and human factors.

In china, the higher education has become more and more popular. According to a study conducted by the Duke University in North Carolina, China educated more than 600,000 engineers per year, much more than US and India[3]. Many problems exist in China’s engineering education: the target of the engineering education is not clear, the programs, curriculums, and content detached from or lag behind actual engineering technologies, teachers engaged has little experience in engineering

fieldwork [4],Students have little opportunity to interact with their teachers and classmates [5]. Additionally, students lack of the capability to connect what they have learned.

Therefore, faced to large amount of information, how to educate students to master some methods to form their own knowledge from information becomes an emergent issue for the educators. We argued applying connection and interaction approach might be helpful in pedagogical practice in engineering education field.

2. EXISTING APPROACH TO PROMOTE CONNECTION AND INTERACTION

During past few years, the SECI model and connectionism were considered as the main method that help organization and people to organize their knowledge creation activities.

2.1 SECI model and its advance and application

SECI model was introduced by Ikujiro Nonaka and Hirotaka Takeuchi in their book-The Knowledge Creating Company-in 1995 which is a kind of dynamic model of knowledge management. Nonaka and Takeuchi viewed knowledge as activity rather than object and focused on knowledge creation, collaboration and practice. They claimed that the knowledge comes from some related or relevant information. The connection between tacit knowledge and explicit knowledge is the foundation of knowledge reconstruction.

Knowledge in action is a cyclic conversion of tacit (difficult to express and subjective) and explicit (codified, objective) knowledge. This knowledge spiral is shown in Fig .1[6].

In SECI model, spiraling process of knowledge creation consists of four steps, that is Socialization, Externalization, Combination, and Internalization. SECI model is used to establish the enterprise standard system [7], evaluate the business competitive forces [8], and it has been extended to the engineering education.

The adaptability of SECI model in education field was tested by some scholars. The literature [9] examines data collected from students at UNSW (University of New South Wales) and proved the SECI model was valid in the Knowledge Management (KM) in education. The literature [10] analyzes the process of the education and study how to improve this process by using the SECI model. The literature [11] considers that the e-learning pattern based on the internet and web2.0 technology which can drive the SECI model in the learning process opened new doors for more personal, dynamic, and social learning. The literature [12] analyzes how to establish the inductive training system by using the SECI model to promote the employees' ability.

In different viewpoints, Andrzej P. Wierzbicki and Yoshiteru Nakamori made some improvement to the SECI model. They proposed a method called Creative Space for integrating diverse approaches to knowledge creation[13]. Shih-Wei Chou and Mong-Young He argue that different types of knowledge assets may have different influences on knowledge creation [14]. They conducted an empirical research which collected data from a wide variety of organizations. A total of 204 usable responses were analyzed in their research. Jian-Xun Chu and Shu-Kun Tang pointed out that the Q-SECI model could explain the application of the abrupt apperception in knowledge creation [15].

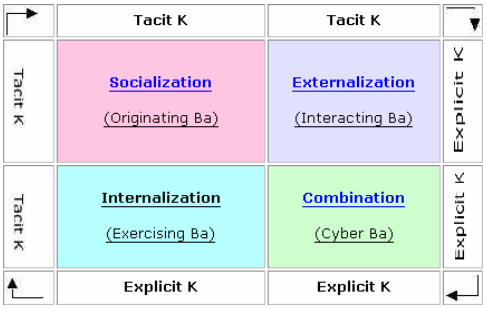

Fig.1 SECI model

2.2 The connection and interaction of knowledge

Connectionism[16] is an approach in the fields of artificial intelligence, cognitive psychology/cognitive science, neuroscience and philosophy of mind that models mental or behavioral phenomena as the emergent processes of interconnected networks of simple units. The connectionism holds the views: 1) A fragment of knowledge is not a description of entity, but a relation between viewer and entity. 2) Learning is perception the acquisition of new patterns of

connectivity.

In the network theory, node and edge is the key elements. Fragment of knowledge can be seen as node, and all the nodes connected to form a network. If the connections of the nodes are changed, the connective intensity of nodes will be able to create new knowledge. The traditional textbook centric learning can be considered as the process of node formation.

2.3 Small world theory

As a transition from completely regular network to completely random network, Watts and Strogtz proposed a small world network model[17] known as WS model in 1998. The small world network is originally proposed to describe the likelihood that the friends of our friends are mutual friends in the context of social networks. In mathematics and physics, the small world network can be viewed as a class of random graphs where most nodes are also neighbors of other nodes, and every node can be reached from every other node by a small number of hops or connections.

The Small world networks exhibit both high Clustering Coefficient (e.g., densely connected in a local neighborhood, big C), as in regular ones, and short average path lengths (small L) as observed in random graphs. It has been shown that a large variety of networks of relevance in applications can yield small world phenomena. Examples include social networks, transportation networks, biological and genetic networks and communication networks [18,19]. The description in [20] provides an interesting physical interpretation of how efficiently information is exchanged on a given network.

The studies in small world network have shown that the network's structure may be characterized by three attributes, the average path length, the clustering coefficient, and the node degree distribution.

- The average path length

The average path length of the network is defined as the mean distance between two nodes, averaged over all pairs of nodes, where the distance between two nodes is defined as the number of edges along the shortest path connecting them.

- The clustering coefficient

The clustering coefficient is the average fraction of pairs of neighbors of a node that are also neighbors of each other.

- The node degree distribution

The degree of a node is usually defined to be the total number of its connections, thus the larger the degree, the potentially more important the node may be in a network, and the average degree over all nodes is called the average degree of the network.

There are two kind of connection method of knowledge: Process oriented connection and content oriented connection. As discussed in Section 2.1, the SECI model can be considered as a kind of process oriented connection between tacit and explicit knowledge, while small world model is applicable to construct the connection among content of knowledge. These viewpoints were emphasizing the connection and interaction of knowledge.

3. NEW APPROACH FOR ENGINEERING EDUCATION

We proposed a new approach for engineering education based on the viewpoint of connection and interaction that aimed to promote knowledge creation capability of students. We also implemented this approach in the course named "the methodology of knowledge innovation" in Southwest Jiaotong University.

Step 1: Concept Change: From textbook centric to problem centric

In the field of engineering education in China, generally speaking, traditional teaching methodology was textbook centric. Teachers often force-feeds information to students, with little concern for helping them understand its relevance and application in the real-world. [21]. In addition, the textbooks themselves always present knowledge about a particular language (elaborated with examples and exercises). They don't support learning strategies about interaction [22]. Therefore, traditional pattern of textbook centric, which lacks interaction between teachers and students, was a passive learning approach and restricted the development of ability of knowledge creation.

However, problem centric is problem directed learning pattern which is able to promote the forming of connection between different technologies and to help people solving problem. The training of innovative ability is the core of engineering education. How to recognize an existing engineering system and explore hidden knowledge to construct a knowledge network is the key of engineering education. For this purpose, we try to apply connection and interaction, a new dimension of teaching and learning, which can and should take into account of curriculum changes and performs as innovative or reform actions in teaching practice. This approach is guided by a new concept of teaching that changes from textbook centric method to problem centric one.

Step 2: Applying the small world network in engineering education

The small-world model inspired us a new approach to make useful connection among huge content of knowledge. We propose some principle below.

- It is supposed that teachers, students are nodes of a learning network, and each node connects with others, courses, contents of course and so on. In this learning network, each node should have a large node degree, a large clustering coefficient and the short average path length.
- Make a core node of knowledge network

Based on the small world network model, each node can connect with others. This implies that the teachers only act as a node in the learning network; students not only connect to textbook and the teacher of the certain course, but also connect to other students and teachers. Moreover, the content of a course have connections with other parts not only intra-discipline but also inter-discipline. In order to achieve high degree of a node, students must act as a core person (node) in human network and select a core problem (node) for their researches further.

- Make tight connection between core node and others around the core

The task of teachers (node) in learning network is to establish a link between students (node) and knowledge that can be considered as other kind of nodes. The process is: teachers introduce the origin, the development of the theory and its relationship with other theories. This approach will guide students to seek for their own interest on this theory by using networks (including social network, internet, etc.). As a result, it will make a tight connection between core node (student) and others around the core (students and key-problem), and the high clustering coefficient will be achieved.

- Make shortcuts to the state of arts of a discipline

In order to shorten the average path length to the state of the art of a discipline, the teacher should make a shortcut to the frontline of such discipline, and clarify the connection with other knowledge or problems. Therefore, the students can get the relevant knowledge of discipline through discussing with the other teachers or students, get the shortcut to the state of arts of this discipline, and a knowledge network will be formed. Even the students can not solve the problem by themselves, they can also benefit from discussing with others, and promote their autonomous research ability through cooperation with others,. Through exploration of the fields, students may find new problems and this is a good start for students to learn how to solve problems and how to create knowledge.

4. CASE INTRODUCTION

The emergence of pattern in technology and knowledge innovation can be raised from the connection and interaction. We developed several cases that reveal how pattern can emerged, and discussed those with students in the course.

4.1 A new pattern in e-Book: Context Reading and Community Reading

(1) The requirements of reading

Human being has a long history of reading, from stone-based, bamboo-based, and paper-based to e-reading. People can read book anytime, anywhere at ease by paper-based reading. But e-reading can only be realized in specific place and special time. Paper-based reading is still a main stream for reading.

The physical conditions of reading can be summarized as follow: A media to present characters and figures- It can be real material or electronic media; Lighting- lighting initiatively or passively; Contrast- big enough to achieve the comfortness to read.

The requirements for reader can be summarized as follow: convenience; portability; personalized requirements, such as bigger font size for elder people; attractive for children.

Compare with paper-based reading, e-reading can achieve customizing requirements. However, e-reading lack the property which paper-based reading has: Customers can read anytime, anywhere at ease.

Here, the implication is the modern reading pattern has to realize both the advantages of paper-based reading and e-reading have. Additionally, it has to support the readers to promote learning capability in the knowledge society.

(2) A new reading pattern: Context Reading and community reading

In order to realize the content oriented connection and interaction of knowledge, we proposed a new reading pattern---Context Reading and Community Reading.

As discussed in section 3, the reading device should support the combination of knowledge, shorten the connection distance (small L) between knowledges, and achieve high Clustering Coefficient (big C). Therefore, the reading pattern can be changed as follow: Context Reading and Community Reading.

Context Reading: a pattern for reader that provide multiple perspectives to survey the context of information, such as the meaning of word, phase and its related event, history, and even some relevant goods or ad.

Community Reading: a pattern for reader that provide timely sharing to exchange the feeling, understanding and question of reading with others in the local area even world-wide.

(3) Technical possibility and requirements

Electronic ink is a display technology designed to mimic the appearance of ordinary ink on an electronic device. The combination of chemistry, physics and electronics technology created this new material[23]。

An electronic book is a new mean of presenting text, which allows the users to download documents and books into a portable computer[24].

When the e-ink, e-paper, e-book and communication technology are combined together, the mobile e-book device can be realized the context reading and community reading in the near future.

4.2 Connection of time-domain and frequency-domain

In the research of engineering technology, the signal analysis and processing is a very important tool. A complex waveform is regarded as a function or analog signal, likewise, as a complex vibration phenomenon which is composed of the superposition of many harmonics with different frequency and amplitude. As the classical method of signal analysis, Fourier Transform (FT) has many advantages， such as orthogonality and completeness. Therefore, FT has become a powerful mathematical tool for the harmonic decomposition, synthesis and analysis of the signal. Through FT, the signal can be represented by using the frequency as independent variable (frequency-domain). FT can link the time-domain and frequency-domain characteristics of the signal. FT is only applicable to deterministic stationary signal and is difficult to fully describe the time-varying non-stationary signal, because the signal spectrum is obtained by using the entire time-domain information and the local time-domain information is not fully utilized [25,26]. As any mutation of the signal, the spectrum will be dispersed in the whole frequency band and the spectrum information in local time can’t be obtained. So it is necessary for us to seek new signal processing tool in order to analyze the time-varying non-stationary signal.

Wavelet Transform (WT) was developed to overcome the shortcomings of FT. In the time-frequency localization processing, WT is of great flexibility and particularly suitable for time-varying non-stationary signal analysis·

Wavelet base has two parameters, scale and time. through the appropriate choice of scale parameter and time parameter, WT provides a flexible time-frequency window, which automatically narrows when high-frequency components are observed, and widens in the case of low-frequency components [27], Which means WT could afford accurate frequency resolution and poor time location in the low-frequency part，while provide accurate time location and bad frequency resolution in high frequency part. The signal can be analyzed from the rough to the detailed described by WT which is beneficial to show the whole panorama of the changing process, and also anatomize the characteristics of local changes.

In conclusion, FT and WT both are signal processing tools which establish the connection of signal from time-domain to the frequency-domain. The time-domain or frequency-domain representation of signal contains the same information essentially, but in the practical application they play different roles. Through the time-domain representation, we can observe directly the change and distribution of signal amplitude with time,, The essential frequency components contained in the signal can be revealed by its frequency representation.

4.3 Power system case

For graduate students, we designed a practical case of power system fault analysis. We try to guide students to use small world model to make a shortcut to the state of art of disciplines.

On August 14th, 2003, a large area of the Midwest and Northeast United States and Ontario, Canada happened to an electric power blackout. The outage affected an area with an estimated 50 million people and 61,800 megawatts (MW) of electric load [28].

Before that, the small world networks theory had been applied to find out how viruses spread among computers and people [29].Inspired by this issue, some scholars pointed out that the topology of the power network might also have a critical impact on the dissemination of failure, which is vital to the efficiency and robustness of the power grid [30]. From then on, more and more scholars began to apply the complex systems theory to studying the power grid vulnerabilities and many results have been achieved. In the network topology analysis by the small-world network model, the power grid in the Western United States is a small world network [31].On the basis of in-depth discussions on the features of small world network model, researcher proved that a large area power grid of China and of the United States were small-world networks. On this way, we can connect small-world network to power gird through taking the characteristics of topology [32].

There are new research ideas to use the characteristics of small-world to analyze power grid. The achievements in collective dynamics of small-world networks are used to advance the analysis of cascading failure in power system. The small-world theory can reasonably explain cascade failure in the power grid [33]. Also, the small-world topological model based on the topology of large-scale power grid analysis and fault simulation chain is used to solve the power network topology analysis and fault chain problems [34] .

In the engineering research, this phenomenon is not rare.

5. EVALUATION

This course made a tentative change in the engineering education. Some students evaluated that compared with other courses, this course is very special. It differs from other basic courses or specialized courses. They said this course changed their normal thinking patterns and released their imaginations. It taught them a sort of method which can guide them to learn and to improve their knowledge creation process. Some other students said in this course, the SECI model gives them an arm to realize the knowledge creation process which can help them to improve their studying. The e-book and the numerator communication technology subjects enlarge their views. The graph theory subject and small world model made them reading the papers easily. This course not only increased their knowledge directly, but also promoted their ability in the scientific research

potentially.

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REFERENCES

[1] Chayant Tantipathananandh, Tanya Berger-Wolf and David Kempe. A Framework For Community Identification in Dynamic Social Networks. KDD'07, August 12–15, 2007

[2] Building the Knowledge Society Information Society Commission. Report to Government, December 2002, Ireland. pp17

[3] US VS INDIA AND CHINA - ENGINEERING GRADUATES STATISTICS. http://www.digi-help.com/pub/us-india-china-engineers-statistics.asp

[4] Xu Kuangdi. Engineering education and technology in a fast-developing China. Technology in Society 30 (2008) 265– 274

[5] Rebecca P. Blust, Scott J. Schneider. Integrating Chinese Students into an American Capstone EngineeringTechnology Design Course, Proceedings of The 2008 IAJC-IJME International Conference, Paper #171, ENT 208

[6] I. Nonaka , H. Takeuchi . The Knowledge-Creating Company, New York: Oxford University, 1995.

[7] LI Zhi-hong, ZHAN Pei-xuan, HE Ji-le. Strategy of Establishing Enterprise Standard System Based on SECI Model. 2007 International Conference on Management Science & Engineering (14th). August 20-22, 2007.

[8] LIU Gang. Appraisal Approaches of Business Competitive forces in an Industrial Cluster. Wireless Communications, Networking and Mobile Computing, 2007. WiCom 2007. International Conference on 21-25 Sept. 2007 Page(s):5361 – 5364.

[9] Cat Kutay , Aybüke Aurum, Validation of SECI Model in Education, Technical Report 0524,National ICT Australia.

[10] Jin-Ying Cui,Yun-Huan Fan. Revelation of the education and teaching by SECI. Culture and education information.2008.4:156-157.

[11] Mohamed Amine Chatti, Ralf Klamma, Matthias Jarke. The Web 2.0 Driven SECI Model Based Learning Process.Seventh IEEE international Conference on advanced learning technologies.2007.

[12] Yue Xia, Strategy research of the inductive training based on the SECI model, Shanghai International Studies University,2007.

[13] Andrzej P. Wierzbicki , Yoshiteru Nakamori . Knowledge Creation and Integration: Creative Space and Creative Environments. Hawaii :The 38th Hawaii International Conference on System Sciences,2005.

[14] Shih-Wei Chou , Mong-Young He . Facilitating Knowledge Creation by Knowledge Assets. Hawaii: The 37th Hawaii International Conference on System Sciences,2004.

[15] Jian-Xun Chu ， Shu-Kun Tang .Conceive a quantum knowledge creation (Q-SECI) model and discuss the principle.Science and scientific management,2006.12:106-110.

[16] http://en.wikipedia.org/wiki/Connectionism

[17] Watts D J, Strogatz S H. Collective dynamics of 'small-world' networks [J]. Nature, 1998, 393(6684):397-498.

[18] V. Latora and M. Marchiori. Economic small-world behaviorin weighted networks. The European Phys. J. B, vol. 32, pp. 249–263, 2003.

[19] X. F. Wang and G. Chen. Small-world, scale-free and beyond. IEEE Circuit and Systems, pp. 6–20, 2003.

[20] V. Latora and MMarchiori, "Efficient behavior of small-world networks," Phys. Rev. Letters, vol. 87, pp. 1–4, 2001.

[21] Learning should be a joy, but traditional teaching methods bore students; [FINAL Edition] USA TODAY. McLean, Va.: Oct 7, 1997. pg. 13.A

[22] The Interactive Multimedia Textbook: Using A Digital Pen to SupportLearning for Computer Programming, Wei-Chu Lai, Po-Yao Chao and Gwo-Dong Chen, Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007)

[23] Hyo Sim Kang , Sun Wha Oh , Mi Na Park , Ju Chang Kim , Young Soo Kang. Synthesis and

characterization of well dispersed electronic ink particles for electronic paper. Department of Chemistry, Pukyong National University, 599-1 Daeyeon 3-dong, Nam-gu, Busan 608-737, Korea.
[24] Thierry Morineau,Caroline Blanche,Laurence Tobin,NicolasKueguen.The emergence of the contextual role of the e-book in cognitive processes through an ecological and functional analysis.Int.J.Human-Computer Studies 62(2005) 329-348
[25] Irving S Reed, Donald W Tufts. Fourier Analysis and Signal Processing by Use of the Mobius Inversion Formula. IEEE Transaction on Acoustics, Speech, and Signal Processing. 1990:38(3):458-469.
[26] Artyon M Grigoryan. Fourier Transform Representation by Frequency-Time Wavelets. IEEE Transaction on Signal Processing. 2005,53(7):2489-2497.
[27] Tapan K Sarkar, C Su. A Tutorial on Wavelets form an Electrical Engineering Perspective, Part 2: The Continuous Case. IEEE Antennas and Propagation Magazine,1998,40(6):36-48.
[28] U.S.-Canada Power System Outage Task Force, lnrerrm Reporr: Coioer of the Ai,gusr 14th Blockout in the UnitedSrotes ond Conodo, Nov, 2003.[Online].
[29] A.L. Lloyd, and R.M. May, “Epidemiology - How viruses spread among computers and people”. Science, 292(5520): pp.1316-1317,2001.
[30] David L. PEPYNE.TOPOLOGY AND CASCADING LINE OUTAGES IN POWER GRIDS. J Syst Sci Syst Eng .Jun 2007.
[31] Watts D J.Small World—The Dynamics of Networks Between Order and Randomness.Princeton(NJ):Princeton
[32] Meng Zhongwei,Lu Zongxiang,Song Jingyan.Comparison Analysis of the Small-World Topological Model of Chinese And American Power Grids.Automation of Electric Power Systems.2004.8.
[33] Le Xu Simon M. Hsiang Mo-Yuen Chow.Cascading Failure Analysis of Bulk Power System Using Small-World Network Model.2004 International Conference on Probabilistic Methods Applied to Power Systems.
[34] DING Ming,Han Ping-ping.Small-World Topological Model Based Vulnerability Assessment Algorithm for Large-scale Power Grid. Automation of Electric Power Systems.2006.4