WIERZBICKI, Andrzej Piotr (2004-2007)

Born June 29, 1937 in Warsaw, Poland

<Degrees>

M.Eng. Telecommunications, WUT-Warsaw University of Technology(1960),Ph.D. Control Engineering WUT (1964), D.Sc. (habilitation), Systems Science WUT(1968), State Title of Professor in Poland (1976)

<Professional Career>

associate professor (1968),professor at Warsaw University of Technology(WUT),Poland(1976),Dean of the Faculty of Electronics,WUT,Poland(1975-1978),Chairman of Systems and Decision Sciences Program in IIASA, Austria (1979-1984), Chairman of the Commission of Applied Research of the State Committee for Scientific Research of Public of Poland (1991-1994), Director General of the National Institute of Telecommunications in Poland (1996-2004), research professor at JAIST, Japan (2004-2007)

Specialties Research Interests Selected Publications (after the year 2000)

Books and book chapters:

・Creative Environments: Supporting Creativity for the Knowledge Civilization Age, Andrzej P. Wierzbicki and Yoshiteru Nakamori, eds. (2007). Springer Verlag, Heidelberg – Berlin, in print

・Creative Space: a Method of Integration of Knowledge Creation Theories, Andrzej P. Wierzbicki and Yoshiteru Nakamori (2006). In A. Kukliński, B. Skuza eds.: Turning Points in the Transformation of Global Scene. Polish Association for the Club of Rome, Warsaw

・Informacyjne aspekty negocjacji (in Polish: Informational Aspects of Negotiations), Andrzej P. Wierzbicki, Kornel B. Wydro (2006). Obserwacje –Wydawnictwo Naukowe, Warsaw

・Creative Space: Models of Creative Processes for the Knowledge Civilization Age, Andrzej P. Wierzbicki and Yoshiteru Nakamori (2006). Springer Verlag, Berlin-Heidelberg

・The Development of Systems Science: Concepts of Knowledge as Seen from the Western and Eastern Perspective, Andrzej P. Wierzbicki (2004). In M. Lucertini, A. Milan Gasca, F. Nicolo, eds: Technological Concepts and Mathematical Models in the Evolution of Modern Engineering Systems, Birkhäuser, Basel

Journal articles:

・A study on knowledge creation support in a Japanese research institute. Jing Tian, Andrzej P. Wierzbicki, Hongtao Ren, and Yoshiteru Nakamori (2006) International Journal of Knowledge and System Science, Vol. 3, No. 1, pp.7-17

・A reference point approach to coalition games. Andrzej P. Wierzbicki (2006), Journal of Multi-Criteria Decision Analysis 13:2-3:81-89

・Creative Space: a Tool for Knowledge Integration, Andrzej P. Wierzbicki, Yoshiteru Nakamori (2004). International Journal for Knowledge and Systems Science, 1, November 2004

・Knowledge Creation Theories and Rational Theory of Intuition, Andrzej P. Wierzbicki (2004). International Journal for Knowledge and Systems Science, 1, November 2004

・Application of Multiple Criteria Evolutionary Algorithms to Vector Optimization, Decision Support and Reference Point Approaches, Andrzej P. Wierzbicki, Marcin Szczepański (2003). Journal of Telecommunications and Information Technology. Warsaw 2003, 3: 16-33.

Message from Yoshiteru Nakamori, the Director of the Center for Strategic Development of Science and Technology

Professor Andrzej P. Wierzbicki joined the COE Program in 2004, since then he has been devoted to developing knowledge creation models in academia, educating our young research assistants, and establishing a world-wide collaborative network, etc. His contribution to our COE program is so high and excellent that we cannot acknowledge it with simple words. We are grateful to him for his scientific production which will certainly help development of knowledge science and innovation research. Since he is a very important scientist and a competent manager also for Poland, we have to accept his wish to return home and to work for his original institute. We believe that he will enjoy a great success in further developing and disseminating his theory of creative space. We thank him again for his great contribution to the COE program.

Prof. Nakamori and Prof. Wierzbicki.

Booklet in Honor of

Research Professor Andrzej P. Wierzbicki

His Years at JAIST

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His Years at JAIST

Photo taken at Nanatsudaki, Nomi.

Center for Strategic Development of Science and Technology

Interview with Research Professor Wierzbicki

Invitation to JAIST

- We heard that when you were a program leader at IIASA (International Institute for Applied Systems Analysis), you met Professor Nakamori and he invited you to JAIST. Could you tell us about this in more detail?

In 1978-84 I served as the leader of the Systems and Decision Science Program of IIASA. I collaborated with Professor Sawaragi from Kyoto University, the teacher of Professor Nakamori; we had frequent visits, and Professor Nakamori also came to IIASA. Later I met Professor Nakamori many times at diverse international meetings, and also often at IIASA; I first came to JAIST for a conference in 2000, and later, when I retired from my position as the Director General of the National Institute of Telecommunications in Poland, Professor Nakamori invited me to come to JAIST COE Program.

- How did you like the mission of making the model of knowledge creation processes?

I was interested and working for a long time – actually, since 1990 – on an evolutionarily rational theory of fallible but powerful intuition, and this is very closely related to scientific creativity. Hence, studying knowledge creation processes in depth was very interesting for me.

Achievements of the 21st Century COE Projects at JAIST

- Please tell us the summary of Nanatsudaki model and the way you completed the model.

Nanatsudaki – seven waterfalls – is a metaphor of seven creative spirals related to the following scientific activities; 1) setting up objectives of research; 2) studying and interpreting scientific activities; 3) socializing for better exchange of tacit knowledge; 4) brainstorming for generating ideas; 5) debating for clarifying ideas; 6) roadmapping, or detailed planning of research; 7) implementing plans, mostly in the form of experimenting. It is a prescriptive model – a kind of instruction how to organize more ambitious and complex research projects, or a toolbox containing diverse tools together with instructions how to use them. The character and order of these prescribed activities results from experience in managing research activities. However, the prescriptive character of this model does not mean that it should be followed literally; the model can be adapted to the context and needs of a particular research project.

- Why was the model named Nanatsudaki? Are there any connections with the model of Nanatsudaki and the waterfall Nanatsudaki?

A model of the creative process is usually a spiral, stressing the creative interplay of rational, intuitive, even emotive knowledge, and the positive feedback character of such processes. A waterfall is a metaphor for such a spiral. Because there are seven spirals in the model and the model was formulated at JAIST, we used the name Nanatsudaki as a metaphor: let each of the seven spirals be as unpredictable and as beautiful as the Nanatsudaki falls.

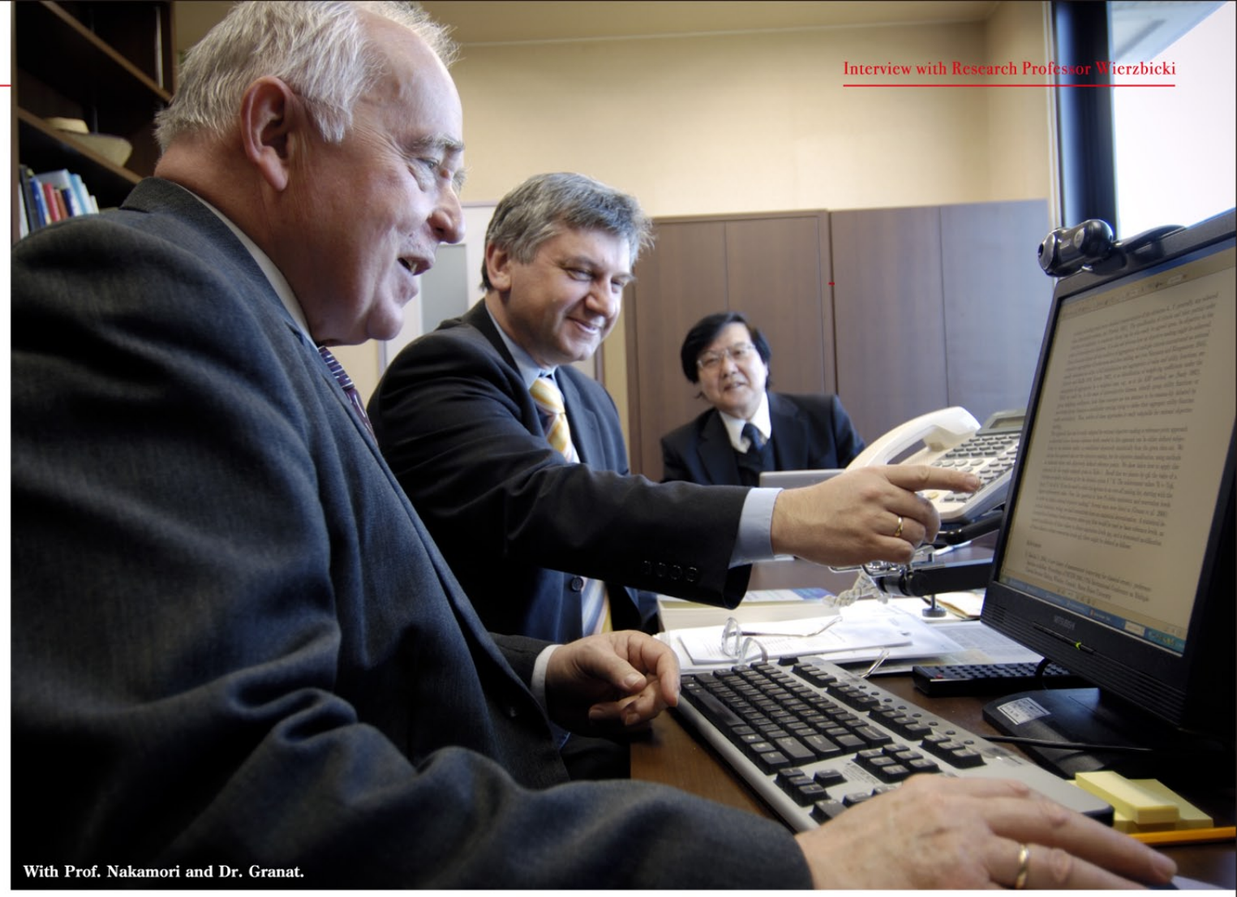
- Could you tell us about books you wrote as the result of your project?

I have written as a co-author many parts, and worked as the co-editor with Professor Yoshiteru Nakamori on two books: *Creative Space: Models of Creative Processes for the Knowledge Civilization Age* (January,2006) and *Creative Environments: Creativity Support for the Knowledge Civilization Age* (April,2007), both published by Springer Verlag.

The book *Creative Space* describes a general meta-model of diverse micro-theories of knowledge creation processes, using the interplay between emotive, intuitive (jointly called tacit) and rational (explicit) aspects of knowledge, as well as individual, group, and human heritage levels of knowledge. The book *Creative Environments* presents the consequences of using such a meta-model for creating diverse tools and systems of computerized creativity such as knowledge acquisition by machine learning, brainstorming, roadmapping,distance electronic learning, etc.

- We heard that you invited some researchers to JAIST as collaborators for your project, for example, Dr. Król and Dr. Granat. Could you tell us about your main collaborators and what kind of work they did to contribute to your project?

Our visitors contributed by writing parts of or entire chapters of the book *Creative Environments*, which we just finished and sent to Springer Verlag for publication. For example, Doctor Król has written Chapter 17 on the emergence of new concepts in science and the role of an intuitive hermeneutical horizon in forming meta-theoretical assumptions about truth of mathematical



With Prof. Nakamori and Dr. Granat.


Discussion with research assistants in the project meeting.

axioms – a very important chapter, although of basic philosophical, Platonian character, since it shows how our intuition can have objective realistic components, and how we can explain the fundamental phenomenon of emergence. Doctor Granat wrote part of Chapter 4 on knowledge acquisition by machine learning and data mining, stressing important conclusions resulting from his experience with application of such methods in telecommunication services – that what computers can learn from people is important, but even more important is what people can learn from other people using computerized support.


At the JAIST campus.

Human Resource Development and the 21st Century COE Program at JAIST

- What is your belief regarding human resource development of the 21st Century COE program at JAIST? And how do you lead RAs in your project?

The 21st Century Center of Excellence program at JAIST is devoted to Technology Creation Based on Knowledge Science, and includes many interdisciplinary projects in which many young researchers are active. The involvement of young researchers and their development based on learning by doing research in the 21st Century COE at JAIST is very important. In this way, human resources are developed for the needs of the knowledge civilization characteristic of the 21st Century. My contribution is mostly directed towards stimulating the creativity of younger researchers – by debating, questioning assumptions, and giving examples of research development.

Your Research and Work

- We heard that you would have a new project at National Institute of Telecommunications in Poland. Could you tell us your new project and your position in the project?

I was Director General of the National Institute of Telecommunication (NIT) of Poland for over 7 years (1996-2003); I retained there a consulting position, and I return there in such a consulting role, as I am already rather old. However, I would like to continue there researching some themes that I started to study at JAIST, such as analyzing creativity conditions and knowledge creation processes in NIT, and in other Polish research institutes with which we cooperate.

Message for JAIST

- Please tell us your message for JAIST.

Having the opportunity, of working at the School of Knowledge Science in JAIST was for me an honor and a great opportunity; JAIST must remember that the School of Knowledge Science is unique in the world and path-breaking, preparing specialists needed for the starting age of knowledge civilization. As usual, there might be questioning of the need for such developments, and discussion about the definition of knowledge science, about its episteme, etc. However, I am deeply convinced that what the School is doing is extremely important and unique, adding to the international reputation of JAIST. Hence, I wish JAIST best success on this road.


Talking with Prof. Nakamori.

Knowledge Sciences and Nanatsudaki Model of Knowledge Creation Processes

—The Proceedings of JAIST Forum 2006 (November 10, 2006)

Andrzej P. Wierzbicki

Introduction

There is no doubt that we live today in a time of informational revolution. However, between many changes that occur nowadays, the most important might be the change of episteme. The episteme – the way of constructing and justifying knowledge, characteristic for a given era or a cultural sphere, as defined by Michel Foucault in 1972 – of the industrial civilization, called sometimes the *modern* episteme, was subjected to a destruction process, particularly visible in the last fifty years. This has lead to a divergent development of separate episteme of three cultural spheres: that of social sciences and humanities, that of hard and natural sciences, and that of technology. Thus, P.C. Snow in 1960 correctly pointed out the development of *two cultures*, but today we should rather speak about *three cultural spheres* and identify that their main differences are epistemic: they use different languages, but more important is the fact that they use different basic epistemic concepts and different ways of constructing knowledge. This leads to basic misunderstandings, visible particularly when social sciences speak about technology.

For example, Bruno Latour (1992) writes about *technoscience*, treating technology as a mere application of hard and natural sciences. This indicates a lack of understanding that *technology is* - in its essence, see, e.g., Martin Heidegger (1954) - *an art of constructing tools and other artefacts needed by humans when dealing with nature*, and is a fundamental human faculty, defining humanity to the same degree as the faculty of discourse, of communicating by language. Moreover, *science* develops *paradigmatically*, see Thomas Kuhn (1962) – following singular paradigms treated as exemplars of theories in hard and natural sciences, or multiple and changing paradigms in social sciences. Contrariwise, *technology does not follow paradigms*, as noted already by Rachel Laudan (1984), I added in (Wierzbicki 2005) that we technologists follow *falsificationism* of Karl Popper (1972), because in our everyday practice we need destructive tests of artefacts and tools in order to improve their reliability (such as we must perform destructive tests on cars in order to improve their safety). Sociologists of science often ridicule falsificationism saying that scientists never try to disprove, they want rather to confirm their theories; this might be true, but they fail to notice that tools are different from theories and falsificationism is necessary in technological construction. We need an increased understanding between these diverse epistemic positions, thus we shall discuss the need of an integrated episteme.

For these reasons, we need also a reflection on the contemporary situation in *knowledge management, technology management*, and the emergence of *knowledge sciences* not only from sociological, but also from technological point of view – and these views should be treated equally, since both social discourse and technological tool-making equally define humanity. After presenting such background, we continue with a short review of recent results in the theory of knowledge creation and introduce a new *Nanatsudaki* model of creative activities, of a prescriptive exemplar character, aimed especially at organizing larger projects of technology creation.

The Need of an Integrated Episteme of the Era of Knowledge Civilization

An important example of the depth of this change of epistemic positions is the switch from reduction to emergence. Reduction means that the behavior of a complex system can be explained by the reduction to the behavior of its parts. Systemic principles of holism and synergy say that the whole is bigger than the sum of its parts. However, the change of episteme is farther reaching. The emergence principle says that new properties emerge with increased systemic complexity and these properties are qualitatively different and irreducible to the properties of the parts. The best practical example is just the concept of software that emerged in the 50s and 60s of last century. It is dependent on hardware, but irreducible to hardware properties. Therefore, it expresses just a different level of complexity. For me, this is the essence of complexity that means much more even than synergy and holism; it is consistent with holism but it says more, it stresses irreducibility that was not stressed by holism.

The destruction of the episteme of industrial era went in three independent directions. Although C.P. Snow stressed the concept of two cultures, but he did not stress nor note that there is a significant difference of episteme between technology and hard sciences. Although hard sciences know very well that we construct knowledge, that the absolute objectivity is impossible, still they search for objectivity and for what they call true laws of nature.

Technology, on the other hand, behaves differently. It is much more pragmatic but insists even stronger on objectivity in the Popperian sense of falsification. We technologists have to submit our products to destructive tests just to test their application area. Therefore, we employ falsification in our normal day to day work. This is essentially different from in science; social sciences point correctly that hard science doesn't necessarily follow Popperian falsification – but fail to note that technology does, in its everyday practice.

Social science episteme was divergent in many directions. The farthest changes could be observed in the postmodernist direction, maintaining that all knowledge is subjective, results from discourse, is constructed, negotiated and so on; that the concept of objectivity serves only to hide the real motivations of power and money, and so on. I will not discuss here in detail with these extreme epistemic positions. I must only note that some of arguments against objectivity are based on an incorrect use of more advanced forms of logic. We know today what is feedback - a dependence of evolving time-streams of effects and causes in the dynamic sense – thus the argument of Bruno Latour (1987, p. 99) against objectivity, "since the settlement of a controversy is the cause of Nature's representation not the consequence, we can never use the outcome – Nature – to explain how and why a controversy has been settled" indicates a clear lack of understanding of the dynamic character of the causal loop in this case and of the circular, positive feedback-supported evolutionary development of knowledge and science. Technology and hard sciences see objectivity today not as an absolute requirement - because it is impossible - but as an idea or value to be pursued, a concept that emerges on a higher level of civilization development, as another example of the emergence principle. Thus, objectivity in science and technology needs power and money to function and can in return produce them, but it is irreducible to power and money, similarly as software is irreducible to hardware.

On this example, we see the importance of developing an integrated episteme of knowledge civilization. Such an episteme is not formed yet, its formation is a big challenge, but it certainly must result from a synthesis from the diverse epistemic positions of those three cultural spheres, and also of Oriental and Occidental culture. Such integration, for me at least, must be based on holistic understanding of human nature including not only discourse and communication, but also tool making abilities. For me,

In the JAIST library.

humanity is defined at least by three fundamental faculties:

- that we use language;
- that we use tools;
- that we are curious about nature and form hypothesis and theories about nature.

These three faculties are for me the defining characteristics of humanity. And the School of Knowledge Science is for me an attempt to work on and prepare such a synthesis, an integrated episteme. It will take long time, however, because the controversies that I presented here are deep, in fact, there are big differences between those three divergent episteme. Therefore, we should speak rather about knowledge sciences in plural, not one knowledge science, until we obtain an integrated episteme of knowledge civilization.

Emergence of Knowledge Sciences

Let us start with the issue of knowledge management versus technology management. The words *knowledge management* I heard first time in Digital Equipment Corporation, used actually first time in the world in early 80s, but to describe a very technical issue of documenting progress on software development. Then I talked to my colleagues from IBM and they told me that they used actually very similar technical solution even earlier, but did not call it knowledge management. These catching words, however, were soon adopted by management science and therefore there are today two ways of looking at knowledge management. One tradition is the management of information relevant for knowledge intensive activities with stress on information technology, knowledge engineering, etc. The other is as management of people in knowledge related processes with stress on organizational theory, learning, types of knowledge and so on.

However, while it is correct that knowledge management cannot be reduced to the management of information, we have here a very beautiful example of a pitfall of binary logic. We use binary logic very often in our industrial episteme and we are usually not aware that it has pitfalls. The pitfall is the following: if you are sure to be right, then the opposite opinion must be wrong; but this way it is easy to overlook the complexity and the essence of the opposite opinion. And complexity of this controversy for me is the fact that knowledge management has started with technology, cannot continue without technology and that knowledge management should therefore be understood from a broader perspective.

The essence of this controversy is that the management of people should be understood as the management of knowledge workers - as it is understood here in School of Knowledge Science. That means also that knowledge workers are very often information technologists. Hence, we should understand knowledge management as management of human resources in knowledge civilization era - concentrating on knowledge workers, their education and qualities, assuming a proper understanding of social sciences, of management science but also of technologists and technology.

Moreover, knowledge engineering or technology management are actually separate disciplines from knowledge management. And they are actually older disciplines. For example, if we take the meaning of the word technology as the art of designing and constructing tools and technological artifacts, which is actually the meaning proposed by Martin Heidegger already in 1954, then the phrase *technology management* should be understood as *managing processes of designing and constructing tools*.

The conclusion of this point is that we observe today an emergence process of new understanding of knowledge sciences. There are many viewpoints that would say "knowledge science is epistemology", or "knowledge science is knowledge management", or knowledge science is something else. However, I would say that we should look at this as a home of several disciplines and I listed them in the alphabetical order:

- epistemology,
- knowledge engineering,
- management science and knowledge management,
- sociological soft system science,
- technological or hard system science,
- technology management.

These disciplines should be put on equal footing with the requirement of mutual information and understanding, even if the differences in corresponding episteme are still great.

Models of Knowledge Creation Processes

I would say that two Japanese approaches contributed to my understanding that we need not only long term philosophical and historical theories of knowledge creation, but also theories of creating knowledge for the needs of today and tomorrow. These were the *Shinayakana Systems Approach* and *the Knowledge Creating Company* with SECI Spiral. I propose to call them *micro-theories* of knowledge creation in order to distinguish them of *macro-theories* that concern long term, historical scale.

The important aspect, particularly expressed by SECI Spiral and knowledge creation theory of Professors Ikujiro Nonaka and Hirotaka Takeuchi, was the stress on the interplay between tacit and explicit knowledge; later we distinguished intuitive, emotional, even mythical aspects of tacit knowledge, and rational aspects of explicit knowledge. This interplay, expressed by spirals of knowledge creation, was an essential element of describing the processes of knowledge creation, following the example of SECI Spiral. With Professor Yoshiteru Nakamori we edited and wrote most parts of the book *Creative Space*. The concept of *Creative Space* means a network-like model of diverse creative processes, including many nodes, many transitions between nodes, and many spirals that can be identified in this general model.

Here is the SECI Spiral of Prof. Nonaka and Takeuchi, well known and most important in showing the significance of the interplay between explicit and tacit and between individual and group aspects of knowledge creation processes. However, we tried simply to distinguish two essential aspects of tacit knowledge, intuition and emotion, and analyze them in the concept of creative space. We called it also explicit knowledge *rational*, because we subtracted from explicit knowledge its emotional aspects and put them into emotional knowledge. We also added a third level to the individual and group knowledge: the knowledge of humanity or the *intellectual heritage of humanity*. We have been following Karl Popper, who said that the domain of the meaning of the world is not only in our minds, as some postmodernist scientists would insist today, but actually in what he called "third world", or "world 3", and we call today the intellectual heritage of humanity. When we observe something new in the outside world, then we interpret it using both the intellectual heritage of humanity and naturally also our own imagination, our own mind. For these reasons, we included this third level as the domain of meaning of the world; see Fig. 2 below for the resulting, basic two dimensions of the Creative Space model.

We used also the model proposed earlier by Prof. Nakamori called I[5] System or the Knowledge Pentagram System; it stresses five elements of knowledge creation processes which are intelligence, involvement, imagination, intervention, integration. This model can be interpreted in diverse ways; but here we used it as an indication of the need of farther dimensions in the Creative Space. This stresses that knowledge creation processes might be quite complex, they have many dimensions and there are many variants of them. For example, the SECI Spiral is preserved in the lower right-hand corner of Fig. 2, but many other knowledge creation processes and spirals can be also distinguished in Creative Space.

Fig. 1 The SECI Spiral

Fig. 2 Basic Dimensions of Creative Space

We also reached the conclusion that we should distinguish between group-based industrial organizational knowledge creation processes, motivated by the interest of the group, and individually based knowledge creation processes in academia. The organizational knowledge creation processes are SECI Spiral, OPEC Spiral introduced by Susan Gasson, and the brainstorming DCCV Spiral, introduced here in JAIST by Professor Susumu Kunifuji; brainstorming is probably the oldest organizational knowledge creation process.

The individually-based knowledge creation processes in academia are motivated by individual needs, for example the most important motivation might be to achieve doctoral degree; knowledge is normally created in academia and at research institutions in slightly different processes than in industrial organizations.

In normal academic knowledge creation, we distinguish three basic processes. One is *hermeneutics*, simply gathering scientific information and knowledge from literature, web, other sources, and interpreting them, reflecting on them. This process is known as *hermeneutic circle*, but can be represented as a spiral. Another basic process is a normal debate that we engage in academia; yet another is experimental knowledge creation and all these processes can be represented as spirals. These three spirals can be switched in between or performed parallel; therefore, we used the concept of *Triple Helix*, although this term was used before to describe other phenomena, but here seems to be most adequate for describing how we can create knowledge in parallel using these three basic processes.

The concept of hermeneutics originally is humanistic, started as interpreting holy texts, then became understood as generally interpreting texts. However, in this sense every other science also uses hermeneutics. For example, physicists also interpret articles or books written by other physicists. Thus, it is an old concept and known knowledge creation process. In our representation of this process as the EAIR (Enlightenment – Analysis – hermeneutic Immersion – Reflection) Spiral, two aspects are new. First, after many humanistic discussions about how to close the hermeneutic circle (see Hans-Georg Gadamer 1960), we propose to close it by the power of intuition and thus represent it as a spiral between rational and intuitive aspects of individual knowledge. Second, we stress the universal role of hermeneutics in knowledge creation, not only for humanistic science studies, also for technology creation, also for hard sciences.

Similarly comments concern the debating EDIS Spiral and the experimental EEIS Spiral; they also represent an interplay between rational and intuitive aspects of knowledge (they might be individual in the case of experiments, but involve also an interplay with group knowledge in the case of debate). The stress of intuitive or tacit aspects of debate and of experiments is also a novel interpretation.

The JAIST Nanatsudaki Model

The essential question that I would like to address today is the issue of *descriptive* versus *prescriptive* models of knowledge creation. The Triple Helix is essentially a descriptive model, describes how we actually create knowledge in normal academic life – and in this sense cannot be absolutely novel, must describe known practices, might only have some novel aspects. However, we need also prescriptive models, suggestions how you should organize the process of knowledge creation to be successful in it. Prescriptive models can be interpreted as technical tools, technological artifacts. SECI Spiral or brainstorming process have the character of prescriptive tools, but we need also a prescriptive model combining organizational and academic knowledge creation.

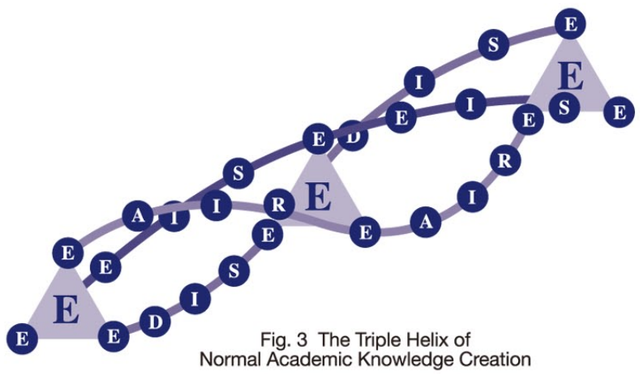


Fig. 3 The Triple Helix of Normal Academic Knowledge Creation

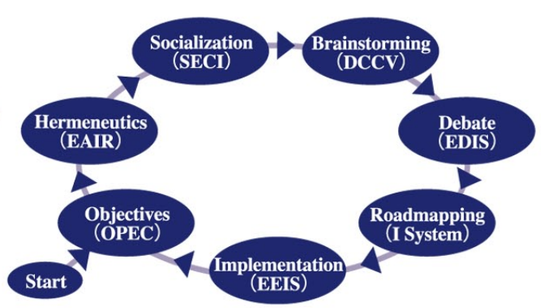


Fig. 4 The JAIST Nanatsudaki Model of Knowledge Creation

Normal academic research processes are different from organizational knowledge-based processes in business organizations. By studying them we could understand the difference and difficulties of cooperation between academia and industry. The problem how to combine them is important for two reasons. First is stimulating, helping cooperation between academia and industry. Second reason is to provide a tool for addressing ambitious, difficult knowledge creation tasks, big projects or research programs. The proposed solution is to combine seven spirals of knowledge creation in a sequence that has a common sense character resulting from our experience both in knowledge management and in actual management of scientific research. The proposed sequence is as follows: 1) set objectives, 2) study literature, 3) socialize, 4) brainstorm, 5) debate, 6) road-map detailed research and 7) implement the research plan with experimental research. Here we assume that the research concerns technology creation based on extensive experiments. This sequence is expressed by seven spirals of the JAIST Nanatsudaki model of knowledge creation.

The name Nanatsudaki relates to the seven beautiful waterfalls that are very close to JAIST and stands for metaphors of knowledge creation spirals. We start with the spiral of OPEC, setting objectives, then go to hermeneutic EAIR Spiral, then go to SECI socialization spiral, then to brainstorming DCCV Spiral, to debating EDIS Spiral, to a roadmapping spiral constructed on the basis of I^5 System; the implementation of all is realized using experimental EEIS Spirals.

The OPEC Spiral was introduced by Susan Gasson as an occidental response to the SECI spiral of Prof. Ikujiro Nonaka. Susan Gasson said we concentrate first on motivation of people through well specified objectives, at least in an occidental organization. I agree with Ms. Gasson on the point that setting objectives is very important. Then actually we should ask every member of the project to go look at literature, at the web, to gather materials, interpret them, reflect on them and think about ideas related to the objectives of the project. Then comes the time for socialization, for brainstorming, debates, planning and roadmapping and for hard experimental work; the related processes in spirals are described in detail in the enclosed materials.

Closure of the Nanatsudaki process might be, for example, a different cycle of the entire process. We need a report of results obtained and therefore reflection on summary of results and so on is needed. Again, socialization might be used to exchange ideas about the importance of future applications of results etc.

There is a question: why did we select precisely this and that many creative spirals to formulate the Nanatsudaki model? One answer is that it results from our tacit knowledge, from our experience in management of big research projects. In that, I personally have a rather long experience. However, this is not sufficient justification; it obviously requires another form of substantiation. Why that many spirals? Because a big project might be addressing diverse needs, diverse aspects and diverse perspectives, you should provide a broad enough assemble of tools. Thus, we should look at this model as at a toolbox and select freely from this those tools only such that are most important. As a technologist, I would naturally say that we need many tools – and hope that we have sufficiently many in that toolbox.

Validation and Tests

We intend to validate the Nanatsudaki Model in various ways; one type of test was already performed with the help of our colleagues, Dr. Tian, Mr. Ren, here at JAIST. The test consisted in a survey of creativity conditions in JAIST; the purpose of the survey was to find what aspects of knowledge creation processes are evaluated by students at JAIST as most critical or most important.

We used three types of questions: assessment questions, assessing the situation at this university; we interpreted as the most critical, truly important questions such that the assessment of the situation was the worst. Second type consisted of importance questions, assessing the impor-

tance of a given aspect of creative processes; the most important were simply such that were evaluated as the best. Third type consisted of controlling questions, just testing the answers to the first two types by indirect questioning. Naturally, we have the organizational structure of JAIST, diverse aspects of students and their national origins, hence we could get diverse cuts through the data set.

Those first two types of questions allowed answers: *very good, good, average, bad, very bad*; we could therefore construct a percentage statistical distribution of answers. The problem of finding worst evaluated assessment questions and best evaluated importance questions can be posed mathematically as ranking of histograms or probability distributions. We applied to this a special method based on reference profiles, reference distributions etc.

At this occasion, another dimension emerged. Typically, decision support is concentrated on subjective ranking support: supporting the subjective evaluation by taking into account preferences of a given, individual decision maker. This is subject of computerized decision support development for the last 25 or 30 years - how to support a subjective evaluation of decision options. However, when we asked Dean Nakamori that he should specify his preferences he said "sorry, I have to present the results of this evaluation to other deans, to all professors in this university and therefore I do not want to specify my preferences; I need some kind of objective ranking; even if I know that the absolute objectivity does not exist, I need as objective ranking of those questions as it is possible."

Thus, we used a simple statistics from these given data sets to define the reference distribution and then compare the distributions of answers to various questions to this statistical reference profile. For research purposes, we modified also the statistical reference profile in various ways (called regular, demanding, and stepwise, which were artificial distributions devised for testing), in order to check the robustness of results. Such a procedure results in a kind of statistical objectivity in a given data set.

An interesting result was that the worst ranked, most critical questions were determined robustly, not influenced by diverse changes of perspectives or parameters or assumptions of distribution. Thus, there was a good agreement of what is worst. The best evaluated importance questions have changed depending on the perspective, but not the worst ones. Thus, the most critical was judged to be following: *language difficulties, tacit knowledge sharing, feedback questions and suggestions in group discussions, organizing and planning research activities, presentations for seminars and conferences, design of experiment and generally generating new ideas*. There was an agreement that these are the worst, most worrisome issues.

In the best evaluated questions, only some were repeated independently of perspective and so on, and these are *learning and training how to do experiments; help and guidance from the supervisor and colleagues and frequent communication of the group*.

The point is that most of these results actually correspond to some elements of academic knowledge creation processes as described by the Triple Helix and the roadmapping I[5] spiral.Thus, it is a partial empirical support for the importance of those three processes and the planning process in the academic research. Naturally, such support can be only partial. It is just common sense that those activities are normal elements of academic research. If you would like to falsify this, you would have to find an example of university that functions without those activities: studying and interpreting literature; debating; experimenting; planning. But even a positive and as objective as possible empirical support from one research institution cannot prove that these elements are essential for all universities. Therefore, we plan other tests, application of a full cycle of the Nanatsudaki in a bigger research project, etc. but we encourage also other people to make such tests.

Conclusions

Conclusions from tests are, first, that the proposed method can be very useful for management. The identification of the worst aspects, not the best ones, turns out to be very important for management purposes. Several aspects of creativity might be improved by introducing, say, new teaching courses. This empirical support for the essential importance of four spirals in normal academic knowledge creation is naturally limited, is based on a survey in only one university. However, also the method of interactive knowledge acquisition from the data set representing survey results, based on reference profiles and objective ranking, turned out to be quite good, so it might be used more broadly.

To summarize: I presented some general reflection of the divergence of the episteme of three cultural spheres and the need of an integrated episteme; on the emergence of knowledge sciences, on the emergence of micro-theories of knowledge creation for the needs of today and tomorrow. I stressed that all such micro-theories take into account the interplay of intuitive, emotional, tacit aspects with rational and explicit aspects. And I also stressed that we found qualitative difference between group-oriented organizational processes of knowledge creation, industrial and market organizations and individual-oriented academic processes of knowledge creation; this was also supported by results of previous and recent surveys. We could try to combine those different knowledge creation processes, but it might be difficult; therefore we proposed the JAIST Nanatsudaki Model as a prescriptive model, as a kind of idea how those two types of knowledge creation can be combined. We had some empirical support for the thesis of importance of such knowledge creation models, but more support is needed, more research on these issues is planned.

What I presented here exemplifies only some of results of our theoretical project in the COE Program JAIST. I believe it is important to provide reflection on knowledge creation processes for the needs of today and tomorrow. With that let me finish. I would be happy to answer any questions from you. Thank you for your attention.

Question-and-Answer Period

Question A I was very interested in the conclusions that you found from these tests. I take it those responses that worse aspects, good aspects reflect mainly the academic environment or an academic environment. Do you think they also reflect the situation in companies?

Prof. Wierzbicki Certainly not.

Question A Could you explain why not?

Prof. Wierzbicki You see, we concentrated on academic environment and these students responding to our survey had the motivation to make a doctoral thesis or a master thesis. Thus, they are not a part of a bigger project that has to develop new technology for market demand. Hence it is quite different. For a study in a firm, in a company you could adapt the same methodology. You could take our questionnaire, our method of comparing, of objective instead of subjective ranking, and so on. But you must devise your own system of questions that would address the reality of an industrial knowledge creation project. Most probably, industrial researchers would not stress the importance of elements of the same spirals that are important for academia. For example, they might stress the importance of some elements of the hermeneutic spiral because they also read scientific literature and study the web, naturally, but not necessarily other spirals.

Question A I understand. I guess my point is that it would be interesting to do that in a large corporate laboratory. Because what you're finding is that although there is frequent communication within the group and good guidance, nevertheless the sharing of tacit knowledge and group feedback are missing in an academic setting and I wonder if we might find the same thing in a large corporate laboratory?

Prof. Wierzbicki The sharing of tacit knowledge is a problem that is very difficult. This is unnoticed in detail in the literature, because the literature

Presenting Nanatsudaki model at JAIST forum.


Answering some questions from researchers and students.

speaks about sharing tacit knowledge but does not go deep into analyzing what tacit knowledge is and why it is difficult to share. From my reflection, the difficulty relates to the dichotomy *verbal* versus *preverbal*, or verbal communication versus multimedia, visual and other media. Tacit knowledge, intuitive knowledge is related to multimedia representation. We share tacit knowledge now in discussion because I'm looking at you and see how you react in our discussion. This is sharing tacit knowledge. But if we only exchange emails, we do not share tacit knowledge. Thus, sharing tacit knowledge is generally a difficult question; therefore, you will probably find the same answer in industrial organization. However, the statement that you are sharing tacit knowledge is difficult, it usually does not answer the question how to improve sharing tacit knowledge.

Question B The study of the knowledge creation process is itself a knowledge creation process. What difficulties - if any - does that produce, the observation of the observer? Or does it generate some kind, in a note to Heisenberg's answer, the same kind of difficulties?

Prof. Wierzbicki I take Heisenberg's uncertainty only as an indication that hard sciences and technologies for 80 years now know (it was the year 1927 when he published his famous paper) that the very fact of measurement influences the measured area. Therefore, absolute objectivity is not possible, and this fact is for a long time known in hard sciences. But we derive different conclusions from that fact then the conclusions of postmodern social sciences. These conclusions and epistemic beliefs are quite different, and thus it is very important that you raise this question, because naturally the models we propose here for knowledge creation processes might biased by our episteme. It is obvious that such a possibility exists. Still, we are trying to be as objective as possible. Thus, I am trying to consider also other epistemic positions, but I cannot help that I am a technologist. I have been a technologist all my life and I admit to follow the episteme of technology, although I tried to understand episteme of other cultural spheres. And you are right in saying that because by proposing some models of knowledge creation we also create knowledge. But the difficulty is precisely the epistemic assumptions which should be, for me, as objective as possible. Does this answer your question?

Question B You said it was a prescriptive model. I mean, who do you think it would be prescriptive for, whether for different groups, managers? Is it going to describe how they should go about knowledge creation, is it describing how research and development institutes should do it, research and development elements within companies, academics. My problem is that the context differs to such a huge degree in each case that I'm not sure how you can have a prescriptive model without studying that context. For example, managers would never follow it because they don't have enough time; academics because there are issues of individual career enhancement and advancement and they are interested in that as much as they are. The context must impact on it, so who is the prescriptive model for?

Prof. Wierzbicki Very good question, but I would first reflect on the concept of prescriptive models. A prescriptive model is, for example, an instruction on how to use, say, MS Word in full with all its details. And anybody who wrote papers in MS Word knows well that he never fully follows this prescriptive model, only selects some aspects that are convenient but knows that if he needs it, he can go to help option and find other things. Thus, the concept of prescriptive model is not the sense that you must follow it, but it specifies what would be good if you have time and resources, what would be ideal, in a sense, to do. I think that in technology we very often have this distinction between prescriptive and descriptive. But the same in medicine; you do not always follow a medical prescription literally.

Second, I am not saying that the Nanatsudaki model should be followed by every manager of a big research project but is certainly useful if the manager wants to combine academic and industrial research, for example, has a big research project involving professors in academia and also his industrial research laboratories. Then it is good to know how to bring them together; and such a skeleton, such a model can help to think how to organize the entire project. I am not saying that they should take every part of it – every prescriptive model is only a toolbox - and I am saying this is a toolbox for bigger research projects.

Suppose you get money from government, suppose professor Stehr gets money from German government for a really big project on the adaptation to the effects of global warming and has many people in this project coming from various sides, from universities, from industry and so on. In such a case, it is not bad to have some skeleton outline how you could organize work in such a project. Only in this sense it is prescriptive; I am not saying it must be followed. Observe that all models of knowledge creation are in a sense open: models such as SECI spiral, as brainstorming processes, are prescriptive but open because they are never followed in full as prescribed, always modified to given circumstances. Prescription should be followed in every detail only in medicine, and even then it is often not followed. Or, to take the metaphor of a toolbox: you have many tools and prescriptions how to use them, but it is your responsibility how you will actually use them; you choose the tool that you need.

Question B My questions here really is an annoying question because I am about to use the word which is always easy to employ. I refer back to your very beginning where you refer to various theories of modern society indicating the novelty and importance of knowledge creation presumably in contrast to past societies, industrial era societies. So given this broad context, I have some difficulty understanding what is new about this knowledge creation process. It reminds me in many ways of the idea of a research university as developed in Germany, 18th and 19th Century, exported to North America in the 19th Century, because these kinds of activities you described in great detail I think were a practiced and formed the core of a research-oriented university in Europe.

Prof. Wierzbicki With that I fully agree. The ideas in those three spirals were not to propose totally new models, they were descriptive. The Triple Helix is descriptive, these three spirals of hermeneutics, debate, experiment describe well known historically and traditionally established reality; they would not be accurate is they were fully original. But they have some novel aspects and I tried to stress what is new. New is the formulation of some of them as spirals; e.g., experimentation was not formulated before, to my knowledge, as a spiral; hermeneutics was formulated early as a circle or, actually, a spiral, but we added some new aspects such as closing it by the power of intuition. New – although following the example of Professor Ikujiro Nonaka - is stressing the interplay between intuition and rationality, tacit and explicit knowledge in them. For example, in experimental studies, at least to my knowledge, there was not enough stress on this interplay, because experiment was simply treated as a fully rational activity; but I am saying from experience that there are important a-rational, experiential and intuitive aspects to experiments. And there are new some details, like stressing that hermeneutic activities are followed also by technologists, not only by humanists. However, we cannot and do not want to be fully original in descriptive theories. I am only saying that if we want to produce knowledge for today and tomorrow, if you want to understand, to know how in minor detail how knowledge is produced or created, then we should have also an in depth description of those three long known and well known processes. Shortly, descriptive must be consistent with that what we know well.

Question B What might be new is that if you abandoned the notion of trying to create a prescriptive model and actually looked at how knowledge was purely created in different context, again in the managerial context, in a research context, because then you would be doing the second order understanding of how knowledge was created in the context in which it is created, which argues for a shift towards a more descriptive rather than prescriptive approach in order to do something new.

Prof. Wierzbicki Yes, but then we have the difference of episteme. I believe in this separation of descriptive and prescriptive because it is important in my technological episteme. What you suggest I understand, but it belongs to another episteme, so somebody else should do it.