Nanatsudaki Model of Knowledge Creation Processes
Andrzej P. Wierzbicki*, **Yoshiteru Nakamori*,
*JAIST, School of Knowledge Science,
21st Century COE Technology Creation Based on Knowledge Science, and
**National Institute of Telecommunications

1. The Creative Space, the Knowledge Pentagram and the Triple Helix
2. The need and character of prescriptive models: the Nanatsudaki Model
3. The Nanatsudaki Model: detailed elements
4. Tests
5. Conclusions
1. The Creative Space, the Knowledge Pentagram and the Triple Helix

Since the Shinayakana Systems Approach (Nakamori and Sawaragi, 1990) and the Knowledge Creating Company (Nonaka and Takeuchi 1995), many theories of creating knowledge for the needs of today and tomorrow emerged.

We might call them micro-theories of knowledge creation, as distinct from the philosophical theories of knowledge creation on the long term, historical macro-scale.

All such micro-theories take into account the tacit, intuitive, emotional aspects of knowledge. Many of them can be represented in the form of spirals of knowledge creation processes, describing the interplay between tacit and explicit or intuitive and rational knowledge, between an individual and a group, following the SECI (Socialization-Externalization-Combination-Internalization) Spiral of Nonaka and Takeuchi.

In Wierzbicki and Nakamori (2006), a synthesis of such micro-theories of knowledge creation takes the form of so-called Creative Space – a network-like model of diverse creative processes with many nodes and transitions between them. Most spirals of knowledge creation can be represented as processes in Creative Space.
1. The Creative Space, the Knowledge Pentagram and the Triple Helix, 2

The SECI Spiral (Nonaka and Takeuchi 1995)
1. The Creative Space, the Knowledge Pentagram and the Triple Helix, 3

Basic dimensions of **Creative Space** (Wierzbicki and Nakamori, 2006)
1. The **Creative Space**, the **Knowledge Pentagram** and the **Triple Helix**, 4

The $I^5$ – **Knowledge Pentagram System** (Nakamori) can be used to indicate further dimensions in the **Creative Space** and further spirals in this space.
1. The Creative Space, the Knowledge Pentagram and the Triple Helix, 5

- As a conclusion from Creative Space, we should distinguish between:
  - **group-based**, industrial organizational knowledge creation processes – such as the **SECI Spiral**, or its Occidental counterpart called **OPEC Spiral** (Gasson 2004), or an older and well known organizational process called **brainstorming** that can be also represented as a **DCCV Spiral** (Kunifuji 2005)
  - **individual-based**, academic knowledge creation processes, describing how knowledge is normally created in academia and research institutions.

- For the latter type, three processes of normal knowledge creation in academia are described in Wierzbicki and Nakamori (2006):
  - **Hermeneutics** (gathering scientific information and knowledge from literature, web and other sources, interpreting and reflecting on these materials), represented as the **EAIR (Enlightenment-Analysis-Immersion-Reflection) Spiral**;
  - **Debate** (discussing in a group research under way, reflecting on the results), represented as the **EDIS (Enlightenment-Debate-Immersion-Selection) Spiral**;
  - **Experiment** (testing ideas and hypotheses by experimental research, interpreting results), represented as the **EEIS (Enlightenment-Experiment-Interpretation-Selection) Spiral**.
1. The *Creative Space*, the *Knowledge Pentagram* and the *Triple Helix*, 6

- The three activities:
  - 1) reading and interpreting;
  - 2) experimenting;
  - 3) debating
- are obviously essential for normal science creation. The corresponding three spirals – *hermeneutic EAIR*, *experimental EEIS* and *debating EDIS* - can be performed parallel or switched between: thus, we can present them as the *Triple Helix*:

  - Triangles: switch between spirals
  - Small circles: transitions in spirals
1. The Creative Space, the Knowledge Pentagram and the Triple Helix, 10

- A projected view of the Triple Helix:
2. The need and character of prescriptive models: the Nanatsudaki Model, 1

- Descriptive models constitute knowledge (typical for science); prescriptive models are tools (typical for technology). E.g., MS Powerpoint is a prescription how to prepare overheads. We need both!
- The Triple Helix indicates that normal academic research processes are essentially different than organizational knowledge creation processes, typical for business, industry, goal-oriented organizations, such as described by:
  - The SECI Spiral (organizational, but of Oriental character);
  - The OPEC Spiral (organizational, but of Occidental character);
  - The Brainstorming DCCV Spiral (goal-oriented, of cross-cultural character, the oldest organizational knowledge creation process, represented as a spiral by Kunifuji 2004);
  - The Roadmapping I$^5$ Spiral (another interpretation of the Pentagram System of Nakamori, goal-oriented, with the purpose of roadmapping or detailed planning of knowledge creation processes)
2. The need and character of prescriptive models: the Nanatsudaki Model, 2

**Problem:** how to combine normal academic and organizational knowledge creation processes, in order to:

- Help in cooperation between academia and industry;
- Provide a tool for addressing ambitious, difficult knowledge creation tasks.

**Proposed Solution:** combine seven spirals of knowledge creation, in a sequence resulting from experience in science management.

**Resulting Model:** a cascade of seven spirals, thus called *Nanatsudaki Model of knowledge creation processes* (originally *Nanatsudaki* denote seven waterfalls on Asahidai hill close to JAIST)

**Proposed Sequence:** OPEC – EAIR – SECI – DCCV – EDIS – l^5 – EEIS, with possible repetitions.

In other words: set objectives – study literature – socialize – brainstorm – debate – plan detailed research – experiment – repeat, all the time remembering the interplay of irrational and rational aspects of research.

**Assumption for this version of Nanatsudaki Model:** the knowledge creation task is based on extensive experiments.
2. The need and character of prescriptive models: the Nanatsudaki Model, 3
3. The Nanatsudaki Model: 1) Objective Setting

- 1) **OPEC Spiral** (Gasson 2004): Objective setting.

No need to go through entire **OPEC Spiral**: the functions of **Expansion** (similar to **Enlightenment**) and of **Closure** will be addressed more thoroughly by other spirals. But an outline of **Objectives** (setting objectives of research) and of **Process** (outlining the stages of the process) is necessary.
3. The *Nanatsudaki Model: 2) Hermeneutics*

- **2) Hermeneutic EAIR Spiral** – reading, interpreting and **reflecting** (next slide). In stage 2), all members of the group working on a research project should start hermeneutic activity.
- This does not mean they this activity is restricted only to stage 2, it should continue parallel to all further stages; but it is essential that some research materials are gathered and reflected upon early. Thus, here at least one full cycle of the **EAIR Spiral** should be completed.
3. The Nanatsudaki Model: 2) Hermeneutics, 2

• The humanistic concept of hermeneutics (interpreting texts) describes the most basic activity for any research – that of gathering from outside sources relevant information and knowledge, interpreting them and reflecting on them.

• A full cycle of the most individual and basic EAIR Spiral consists of:
  - **Enlightenment**, having a research idea, then following it with ideas where and how to find research materials;
  - **Analysis**, which is a rational analysis of the research materials;
  - **Hermeneutic Immersion**, which means some time (Ma) needed to absorb the results of analysis into individual intuitive perception of the object of study;
  - **Reflection**, which denotes intuitive preparation of the resulting new ideas.

• Hermeneutics is well recognized in philosophy and humanistic studies; the novel aspects of EAIR Spiral are closing the hermeneutic circle by the power of intuition, and stressing the universal role of hermeneutics in knowledge creation, also in hard science and in technology.
3. The Nanatsudaki Model: 3) Socialization

3) SECI Spiral – Socialization. We could perform here all transitions of SECI Spiral, see e.g. Nonaka and Takeuchi (1995); but most important in our context is Socialization.
3. The **Nanatsudaki Model: 3) Socialization, 2**

- We give here a slightly different interpretation of these transitions:
- **Socialization**, which actually means sharing intuitive perceptions in an informal meeting;
- **Externalization**, which can be explained as rationalizing the intuitive knowledge of the group;
- **Combination**, developing detailed plans and directives for individual group members;
- **Internalization**, increasing individual intuitive perception – tacit knowledge - while learning by doing.

- However, in the **Nanatsudaki Model** we can use spirals in further stages to perform in more detail the function of either **Externalization** (as in **Brainstorming** and in **Debate**) or of **Combination** (as in **Roadmapping**) or even of **Internalization** (as in **Implementation**). Thus, the entire **Nanatsudaki Model** can be interpreted as an enhanced **SECI Spiral**.

- In its separate part that is directly related to **SECI Spiral** it is sufficient to perform only the **Socialization**. It is, however, an important part; without **Socialization**, the following **Brainstorming** and **Debate** might be not very effective.
3. The Nanatsudaki Model: 4) Brainstorming

- 4) **Brainstorming DCCV Spiral – Divergence.** The full cycle of the DCCV Spiral can be performed:
  - **Divergence:** generating and listing as many ideas as possible;
  - **Convergence:** selecting most helpful ideas;
  - **Crystallization:** improvement of the best ideas;
  - **Verification:** applying and thus testing these ideas;
- but in the **Nanatsudaki Model,** concentration on the **Divergence** transition suffices.
3. The *Nanatsudaki Model: 4) Brainstorming, 2*

- This is because the **Divergent** thinking transition is essential here to generate as many and as wild ideas as possible, and **Convergent** thinking is helpful to organize these ideas, but further transitions of **Crystallization** and of **Verification** are in more detail supported by the next spiral of **Debate** and the final spiral of **Experiments**.

- However, the **Divergent** thinking transition is extremely important for the success of the entire creative process: it mobilizes the full imaginative power of the group to generate new ideas.

- During this transition, we should fully observe the rules of divergent thinking – **do not criticize, develop creatively even the wildest ideas**. However, the next **Convergent** thinking transition requires switching back to a critical and synthetic attitude; since this never occurs easily, it is better to switch to another spiral for the **Crystallization** of ideas.
3. The Nanatsudaki Model: 5) Debate

- 5) *Debating EDIS Spiral* – Critical Debate. We use the transition *Debate* for a rational organization of ideas. We separate this stage from the former *Brainstorming* by some time (*Ma*) in order to immerse the results of the former stage into intuition of project participants.

- The debate is a part of detailed realization of the difficult stages of *Combination* from *SECI Spiral* or *Crystallization* from *DCCV Spiral*.
3. The Nanatsudaki Model: 5) Debate, 2

- **Intersubjective EDIS Spiral** is also one of the most fundamental and well-known processes of normal knowledge creation in academia:
  - After having an idea due to the **Enlightenment** phenomenon, an individual researcher might want to check it intersubjectively,
  - Scientific **Debate** actually has two layers: one is verbal and rational, but after some time for reflection (**Ma**) we also derive intuitive conclusions from this debate.
  - This is the extremely important and in fact difficult transition called **Immersion** (of the results of debate in group intuition); it occurs as a transition from group rationality to group intuition.
  - An individual researcher does not necessarily accept all the results of **group intuition**, she or he makes his own **Selection** in the transition from group intuition to individual intuition.
- This process can gain momentum by repetition: second **Debate** might be much enriched by group intuition resulting from **Immersion**; this is called the **Principle of Double Debate**.
- New in this description is stressing the interplay of rational and intuitive aspects of knowledge, emphasizing the power of **Immersion** and the **Principle of Double Debate**.
3. The Nanatsudaki Model: 6) Roadmapping

- 6) Roadmapping $I^5$ Spiral – detailed planning of further research:
  - **Intelligence**: summarizing all results of individual hermeneutic activities for the group use;
  - **Involvement**: consultations with the future users of the results of research project;
  - **Imagination**: immersing the consultation outcomes, preparing the ground for a new integration;
  - **Integration**: working out a mature form of the roadmap for further research activities.
3. The *Nanatsudaki Model: 7) Experiments*

- **7) Experimental EEIS Spiral** – perform detailed experiments
- We assume experimental character of entire project, thus experiments might take most of research time
3. The *Nanatsudaki Model: 7) Experiments, 2*

- Recall that the spiral consists of the transitions:
  - *Enlightenment* meaning the creation of an idea of an experiment;
  - *Experiment* performing the actual experimental work;
  - *Interpretation* of the experimental results reaching into intuitive experimental experience of the researcher;
  - *Selection* of ideas to stimulate a new *Enlightenment*.
- This cycle should be repeated as many times as needed and with such support as needed.
- The support should include interactive experiment planning; although the former stage of *Roadmapping* includes preliminary experiment planning, the results of current experiments and their interpretation always – at least, in a creative experimental work – imply changes in experiment planning.
- The support should include also experiment reporting, an extremely important aspect of experimental groupwork.
3. The Nanatsudaki Model: 8) Closure

- **8) Closure: a different cycle of entire process**
  - How the process of Nanatsudaki Model should end? A report of results obtained, a reflection on this summary of results, on their possible future implications and use, is always necessary upon completing a research project or an important stage of it.
  - *We suggest to use for this purpose another cycle of the entire Nanatsudaki Model process*, suitably modified and shortened, if necessary, to fit the purpose of reporting or to summarizing the results.
  - For example, a new *Socialization* might be used to informally exchange ideas about the importance and future applications of results; *Brainstorming* might be performed again, if some future applications deserve it; *Debate* might help in the best summary and presentation of entire project; *Roadmapping* and *Implementation* might be not needed, but a review of original roadmap comparing it with actual developments might be helpful in reporting.
4. Tests

• A question might be asked: *why did we select precisely these* creative spirals and this particular order of them? We did it *on the basis of our intuitive, tacit knowledge, resulting from many years of our experience in the management of research activities*; and the validation of any prescriptive model requires its application.

• Even if such response gives some justification to the *Nantsudaki Model*, it does not provide its full substantiation.

• Therefore, we validate the *Nantsudaki Model* in several stages. One is already performed and consisted in a survey of opinions about creativity conditions between young researchers – master students, doctoral students and research associates – at JAIST (thus, in academic environment – mostly testing the spirals of *Triple Helix*).

• The purpose of the survey was to find what aspects of knowledge creation processes are evaluated as either *most critical* or *most important* by responders.

• On this occasion, we tried also a new approach to *interactive knowledge acquisition from complex data bases*. 
4. Tests, 2

• A long questionnaire was prepared (J. Tian); it consisted of total of 48 questions, organized in five parts.
• The questions were of three types:
  - **Assessment questions**, assessing the situation at the university; the **most critical** questions of this type are those that correspond **worst** to a given reference profile.
  - **Importance questions**, assessing importance of a given subject; the **most important** questions might be considered as those that correspond **best** to a reference profile.
  - **Controlling questions**, testing the answers to the first two types by indirect questioning revealing student attitudes or asking for a detailed explanation.
• The responders were subdivided corresponding to:
  - The organizational structure of JAIST, three schools: of material science, of information science and of knowledge science;
  - Their character: master students, doctoral students, research associates;
  - Their national origin: Japanese and foreign.
4. Tests, 3

- All questions of first two types – *assessment questions and importance questions* – allowed five options of answers, variously called but signifying similar opinions: “very good – good – average – bad – very bad” or “very important – important – indifferent – not important – negatively important”. Thus, answers to all questions of first two types can be evaluated on a common scale, as a *percentage statistical distribution of answers* VG – G – A – B – VB, while a different wording of the answers would be appropriately interpreted.

- Some questions or scale of answers were reversed, stated negatively, for testing the concentration of responders, but this can be also taken into account just by reversing the scale. Special attention should be paid to:
  - *The worst evaluated assessment questions* of the first type, indicating some *critical conditions* for scientific creativity;
  - *The best evaluated importance questions* of the second type, indicating *most important issues* in the opinion of responders.

- Thus, the problem might be posed as a *ranking of histograms or probability distributions*. 
4. Tests, 4

• A special reference profile (or reference distribution, since it has a statistical interpretation) approach to knowledge discovery in data bases was developed for ranking the answers to the questions, finding the best and the worst evaluated questions.

• The issue of objective ranking was also included (in interactive decision making, every ranking is subjective; but in experimental testing a theory, or even when ranking the importance of issues for management, we need as much objectivity as possible).

• A special software system (H. Ren) was developed for computing the distributions of answers, defining and changing reference profile distributions, computing ranking lists of questions, repeating these computations for all or part of responders – e.g., for foreign students, or doctoral students, or students of a given School of JAIST, etc.

• For research reasons, beside two achievement functions (…), four different types of reference profile distributions were compared: Average - actual average of all responders and questions, which results in a statistical objectivity in a given data set; Regular, Demanding, and Stepwise - artificial distributions devised for testing.
4. Tests, 5

- Both types of achievement functions, with various parameter values and with these four reference distributions were used and the results compared. This **variety of ranking approaches:**
  - Two types of achievement functions;
  - Four values of parameters for each achievement function;
  - Four reference distributions;
- was compared in order to test **the robustness of conclusions**
- **It was found that:**
  - Changing the achievement function or the type of reference distribution does not essentially, qualitatively change the questions evaluated as **worst, most critical**; it influences, although in some sense predictably, the **best, most important** or best provided for.
4. Tests, 6

- In eight worst evaluated questions, almost all (seven) were consistently repeated independently of these changes; thus, we can count them as the most critical questions of the first type. These are questions related to not good enough situations concerning:
  1) Because of language reasons, difficulty in discussing research questions with colleagues from other countries;
  2) Easiness of sharing tacit knowledge;
  3) Critical feedback, questions and suggestions in group discussions;
  4) Organizing and planning research activities;
  5) Preparing presentations for seminars and conferences;
  6) Designing and planning experiments;
  7) Generating new ideas and research concepts.
- In the eight best evaluated questions, the following questions of the second (importance) type were consistently, independently of these changes, listed as most important:
  1. Learning and training how to do experiments;
  2. Help and guidance from the supervisor and colleagues;
  3. Frequent communication of the group.
4. Tests, 7

- Most of these results actually correspond to some elements of the three spirals of normal academic knowledge creation:
  - Intersubjective EDIS (Enlightenment-Debate-Immersion-Selection) Spiral – items 2), 3) and 5);
  - Experimental EEIS (Enlightenment-Experiment-Interpretation-Selection) Spiral – item 6);
  - Hermeneutic EAIR (Enlightenment-Analysis-Immersion-Reflection) Spiral – item 7).
  - However, they also stress the importance of another spiral of research planning: Roadmapping (I-System) Spiral – item 4).
- This conclusion is supported by the positive evaluation of the importance of other elements of these spirals in response to questions of the second type (1., 2., 3.) – and also by the answers to indirect questions of the third type.
- The question, however, is: how objective is such empirical support for the essential importance of the three spirals of normal academic knowledge creation contained in the Triple Helix and the Roadmapping Spiral?
4. Tests, 8

- It is just common sense that:
  - reading scientific literature,
  - debating,
  - experimenting,
  - research planning
- are normal elements of academic research (*to falsify this, find a university that functions without them*).
- However, even a positive, as objective as possible empirical support from one research institution cannot prove that these elements are essential for all universities; many falsification attempts are needed to be reasonable sure of their importance, further research is necessary.
- Thus, other tests are intended; they might consists in an application of the full cycle of the *Nanatsudaki Model* in a research project; or performing similar questionnaire research in other research institutions.
4. Tests: conclusions

• The example of the evaluation of the results of the survey of conditions for scientific creativity shows that the proposed method can be very useful for management, as in the particular case it was found useful by university management:
  ➢ In identifying several issues of creativity that might be improved, e.g., by introducing new teaching courses;
  ➢ In detailed critical comments from individual responders.
• Other conclusion from this example is a (naturally limited) empirical support for the essential importance of the four spirals:
  ➢ the Intersubjective EDIS Spiral,
  ➢ the Experimental EEIS Spiral,
  ➢ the Hermeneutic EAIR Spiral, and also:
  ➢ the Roadmapping (I-System) Spiral of planning research processes.
• In general, this example shows that the use of interactive knowledge acquisition – that is, a multiple criteria formulation and reference profiles for knowledge acquisition from complex data sets - gives very promising results and should be applied more broadly.
5. Conclusions - general

- We commented on the emergence of *knowledge sciences*, including *epistemology, knowledge engineering, management science with knowledge management, sociological (soft) systems science, technology management, and technological (hard) systems science*.
- Many new *micro-theories* of knowledge creation for today and tomorrow emerged since 1990. All such micro-theories take into account the interplay of intuitive and emotional, tacit aspects of knowledge with rational and explicit aspects.
- There is a qualitative difference between group-oriented *organizational* processes of knowledge creation in industrial and market organizations and individual-oriented *academic* processes of knowledge creation; the latter can be described by a *Triple Helix* of academic knowledge creation.
- Combining both organizational and academic processes of knowledge creation is the prescriptive *Nanatsudaki* model of seven creative processes.
- The importance of diverse elements of these models was empirically supported by the results of a survey of creativity conditions in a Japanese research university, using multiple criteria decision making for *interactive knowledge acquisition* from complex data bases.