

Towards Creative Environments: Conclusions from Creative Space

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Abstract

In recent papers and a book [1], [2], we have investigated diverse types of knowledge creation processes based on the concept of Creative Space (a metamodel of knowledge creation processes). This paper comments first on recent changes of understanding the problem of knowledge and technology creation, then recalls the concepts of Creative Space and diverse spirals and models of processes of knowledge creation discerned in this space, including the Triple Helix of normal knowledge creation. This is followed by comments on a new understanding of the role of systems science in the new era of knowledge civilization. Based on these results, we present a review of the needs and possibilities of constructing diverse types of dedicated Creative Environments (information technology systems for supporting creativity) for knowledge and, in particular, technology creation.

Keywords: knowledge creation, integration and management, technology creation, environments for creativity support

1. Introduction: recent changes of understanding the problem of knowledge and technology creation

In [1] and [2], we presented the concept of the *Creative Space* and its applications. Before reviewing them, we recall some of related preliminary concepts.

In the last decade of the 20th Century and in the beginning years of the 21st, the need for a better understanding of knowledge creation processes in time of the knowledge based economy resulted in a revolutionary change. Many *micro-theories of knowledge creation* were proposed (describing knowledge creation needed for today and tomorrow) as opposed to the classical concentration of epistemology either on *knowledge justification* or on diverse *macro-theories of scientific change* (describing knowledge creation on a grand historical scale). First signs of the paradigmatic change were the *Shinayakana Systems Approach* [3] and the organizational knowledge creation theory *SECI Spiral* [4]. The possibility of their integration and generalization was given by the *Rational Theory of Intuition* [5].

These contributions came not from philosophy, but from system science or management science, motivated

by the needs of the knowledge economy and the informational or knowledge civilization. In philosophic, purely epistemological terms, a theory of basic knowledge creation in times of a scientific revolution was given in [6]. Many other such theories emerged recently, mostly originating from system science or from management science, e.g. the *I⁵ (Pentagram) System* [7] analyzing many dimensions of creativity. All such theories take into account the *tacit, intuitive, emotive, preverbal* aspects of knowledge creation.

Preverbal is related to *multimedia* information, which is known to be much richer than *verbal* or textual information. The coming change of the way of recording our human intellectual heritage – *from simple printed text to electronic multimedia form* – will thus have as great an impact on the understanding of our human traditions as the historical introduction of widely usable printing technology by Gutenberg. This can be called ***multimedia principle***; this principle can be also evaluated quantitatively. It is known in telecommunications that video requires at least 100 times more bandwidth than audio; similarly, in computational complexity theory it is known that processing complexity increases strongly nonlinearly with the amount of data processed. It follows (see [1] for a more detailed analysis) that:

- *Language is only an inadequate code*, simplifying the processing of information about real world at least 10⁴ times, thus each word – out of necessity – has many meanings. Therefore, *an absolutely exact, objective truth and knowledge are not possible* – not because human knowing subject is imperfect, but because humans use imperfect tools for creating knowledge, starting with language.

The relativity of truth is thus evident – but the importance of truth, of objectivity, emerges on much higher level of civilization development than just the level of interpersonal communication, constituting an important even if unattainable goal and ideal for science and technology development.

This is related (see [1] for a detailed substantiation) to another, equally fundamental ***emergence principle***:

- We observe *the emergence of qualitatively new properties and concepts* at higher levels of complexity of complicated systems. These properties and concepts are *irreducible*, thus in a sense

transcendental to those used on lower levels of complexity.

The emergence principle was *substantiated empirically* by the concept of punctuated evolution in biology. Parallel, it was *substantiated rationally* first by the deterministic theory of chaos, then by its probabilistic version, both originating from the mathematical theory of nonlinear dynamic systems and from computational sciences including hierarchical systems theory. Finally, it was also *substantiated pragmatically*, i.e., introduced experimentally by telecommunications as the only practical way of dealing with complexity of modern computer networks.

Almost all philosophy and science of 20th century concentrated on *reduction principle*, that is, on explaining the properties of complex systems by the properties of their elementary parts. Today, at least when analyzing the processes of knowledge and technology creation [1], that principle must be replaced by the above *emergence principle*.

- Thus, we should ask today new questions, e.g., *whether the deconstruction of objectivity by social postmodernist philosophy is valid, whether it is not an attempt to criticize concepts from a different, higher level of complexity by trying to reduce them to much more elementary level of interpersonal communication.*

From the *change between reduction and emergence*, as well as from the fact that *words are but poor approximations of reality*, it follows that we must critically rethink all philosophy, all ontology and epistemology that focused in 20th century mostly on language, words, communication, see, e.g. [8].

The development of language was a great simplification and a great evolutionary shortcut that suppressed, however, older and cognitively stronger abilities of the human mind.

- Intuition is such ability – the ability of *preverbal, holistic, subconscious* (or *unconscious*, or *quasi-conscious*¹) imagining and processing of sensory signals and memory content, left historically from the *preverbal stage of human evolution*.

This definition is an *evolutionary rational definition of intuition*, because it is deeply related to the evolution of human civilization, because it follows rationally from a set of well justified assumptions and because we can draw from it diverse conclusions that can be variously tested – by comparison with other parts of knowledge or even empirically. These conclusions include practical methods of stimulating creative *Enlightenment* (an essential phase of many creative processes, variously called *eureka*, *illumination*, *aha* – denoting simply having an idea, big or small). This definition has a strong explanatory and predictive power; an entire *Rational Theory of Intuition* [4] has been developed and extended in [1] based on this definition.

¹ Meaning an activity that we are aware of doing but we do not concentrate our consciousness on doing it.

The rest of the paper is organized as follows. We recall first from [1], [2] the concept of *Creative Space* and related concepts and results, in particular diverse models of creative processes. Next we turn to related changes in the understanding of systems science, postulating some new principles of systemic integration. Finally, we apply such models of creative processes and such systemic integration principles to explain the concept and to list needed types of *Creative Environments* – software and informational technology artifacts used for supporting processes of knowledge and technology creation.

2. The concept of *Creative Space*

The concept of *tacit knowledge* introduced in [9] and used in [4] can be better understood by dividing it into *intuitive* and *emotive knowledge*, while the latter also contains emotional elements of *explicit knowledge*. Each knowledge creation process, beside its *individual* and *group* aspects, also depends critically on the *intellectual heritage of humanity*. The *individual*, *group*, and *heritage knowledge* – elements of the *social dimension*² of knowledge creation processes – can be again classified as *rational* (*explicit*, but without its *emotive* elements), *intuitive*, *emotive* elements of *epistemological dimension* of knowledge creation processes.

- This three-by-three matrix (*individual*, *group*, *human heritage* versus *emotive*, *intuitive*, *explicit knowledge*) constitutes the starting point of *Creative Space*, a network-like metamodel of knowledge creation processes that is a generalization of *SECI Spiral* [4]. The elements of this space are called *nodes* and *transitions* between the nodes (we repeat here – after [1], [2] – Fig. 1 illustrating the concept of *Creative Space*, its *nodes* and *transitions*).

The nodes of *rational*, *intuitive* and *emotive heritage of humanity* are especially important: *rational heritage* corresponds to (most of) the *third world* of Popper, *emotive heritage* contains all human arts, but also the *collective unconscious* of Jung, *intuitive heritage* corresponds to *a priori synthetic judgments* of Kant.

As shown in [2], already in this starting version of *Creative Space*, several known processes of knowledge creation can be represented: the *SECI Spiral* (*Socialization-Externalization-Combination-Internalization*) of Nonaka and Takeuchi [4], the *OPEC Spiral* (*Objectives-Process-Expansion-Closure*) of Gasson [10], the *ARME Spiral* (*Abstraction-Regress-Mythologization-Empathization*) of revolutionary knowledge creation as proposed by Motycka [6], utilizing the emotive heritage; a new *EDIS Spiral* (*Enlightenment-Debate-Immersion-Selection*) can be proposed [11], describing the process of normal knowledge creation by intersubjective debate in academia (universities and research institutes), well known in research practice.

² We use the words *social dimension* in the belief that they describe more precisely what was originally called *ontological dimension* in [3].

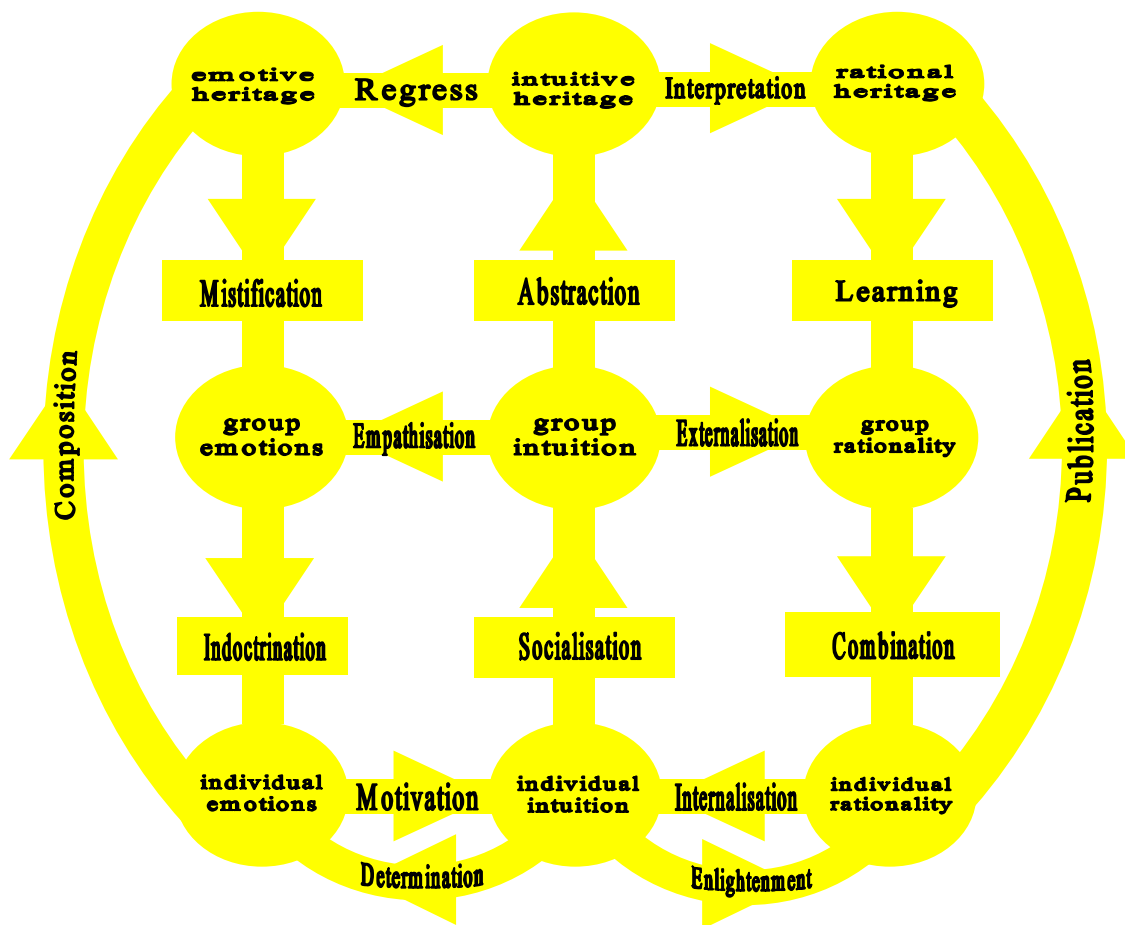


Fig. 1. Two basic dimensions of the creative space

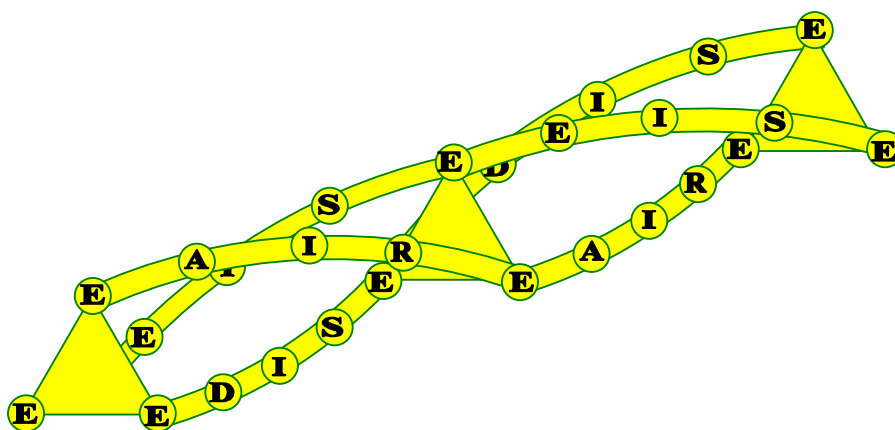


Fig. 2 *Triple Helix* of normal knowledge creation

However, knowledge creation processes are extremely diversified and many more dimensions of *Creative Space* are necessary to describe them in detail. The starting point for this extension is the I^5 (*Pentagram*) *System* [7]. Beside *Intelligence* and *Involvement*, which are analogous to the *epistemological* dimension of *Rational*, *Intuitive*, *Emotional* and to the *social* dimension of *Individual*, *Group*, *Humanity heritage*, three other dimensions are suggested by the *Pentagram* (each represented by three levels): *Imagination* (*Routine*, *Diversity*, *Fantasy*), *Intervention* (*Drive*, *Dedication*, *Determination*), *Integration* (*Specialized*, *Interdisciplinary*, *Intercultural*). Moreover, even these five dimensions are not fully sufficient, five other dimensions are proposed in [1] for consideration: *Abstraction* (*Applied*, *Basic*, *United*), *Objectivity* (*Subjective*, *Intersubjective*, *Objective*), *Hermeneutic Reflection* (*Basic*, *Integrated*, *Critical*), *Cross-cultural* (*Oriental*, *Occidental*, *Brainstorming*), *Organizational* (*Accountable*, *Discretionary*, *Autonomous*), see also [12]. These all additional dimensions might overly complicate the *Creative Space*, but they make it possible, see [1], to add several important spirals of knowledge creation.

One is a new *Brainstorming DCCV Spiral* (*Divergence-Convergence-Crystallization-Verification*) representing the known process of *brainstorming* e.g. in the form suggested by Kunifuji [13]. Two other are important components of any normal processes of knowledge creation in academia: *Hermeneutic EAIR Spiral* (*Enlightenment-Analysis-Immersion-Reflection*) and *Experimental EEIS Spiral* (*Enlightenment-Experiment-Interpretation-Selection*). Jointly, the processes of normal (in the Kuhnian sense) knowledge creation in academia, at universities and in research institutions are represented by at least three intertwined spirals: *Hermeneutic EAIR*, *Experimental EEIS* and *Intersubjective EDIS*; in order to stress this fact, a joint representation of these three spirals is proposed in [1] as a *Triple Helix of Normal Knowledge Creation*. We repeat here the illustration of the *Triple Helix*, see Fig. 2, because of its integrative character. In Fig. 2 we employ slightly different graphical representation code than in Fig. 1: the triangles represent the transition *Enlightenment* (*illumination*, *aha*, *eureka* – having a bigger or smaller new idea) which can occur in any of the three spirals, but is common to all of them, thus the idea can be used afterwards in another spiral; small circles represent diverse transitions: *Analysis*, *Hermeneutic Immersion*, *Reflection* in the *Hermeneutic EAIR Spiral*; *Experiment*, *Interpretation*, *Selection* in the *Experimental EEIS Spiral*; *Debate*, *Intuitive Immersion*, *Selection* in the *Intersubjective EDIS Spiral*.

These three spirals of normal knowledge creation in academia and research institutions will be discussed in a further section in more detail in relation to the concept of *Creative Environments*. Here it is sufficient to stress that they represent the most basic components of normal knowledge creation:

- The search in literature and in the web of results related to a creative idea, the interpretation and analysis of the results of such search, the comparison of the results with the tradition of a given field and a deep intuitive reflection on this comparison that might lead to new ideas in the case of *Hermeneutic EAIR Spiral*;

- The experimental testing of a creative idea, the interpretation of results of the experiment, the intuitive selection of results that might lead to new ideas in the case of the *Experimental EEIS Spiral*;

- The debate of an idea in a group of researchers, the immersion of the results of the debate in group intuition with a possibility of repeated debate, the intuitive selection of such results of the debate that might lead to new ideas in the case of the *Intersubjective EDIS Spiral*.

The researcher can switch from one to another spiral (this is the meaning of the triangles in Fig. 2) depending on the character of research and the tradition of the discipline.

Thus, the concept of *Creative Space* results in an integrated description of diverse knowledge creation processes presented in [1]:

- 1) Three spirals of organizational knowledge creation, typical for market-oriented organizations: *Oriental SECI Spiral* (Nonaka and Takeuchi), *Occidental OPEC Spiral* (Gasson), and *Brainstorming DCCV Spiral* (Kunifuji);

- 2) Three spirals of normal academic knowledge creation, typical for normal scientific activities at universities and research institutes: *Hermeneutic EAIR Spiral*, *Experimental EEIS Spiral*, *Intersubjective EDIS Spiral*, that can be represented together in the *Triple Helix of Normal Knowledge Creation*, all proposed in [1];

- 3) One spiral of revolutionary scientific creation processes: *ARME Spiral* (Motycka);

- 4) Two general systemic models of knowledge creation and integration: *Shinayakana Systems Approach* (Sawaragi and Nakamori) and I^5 (*Pentagram*) *System* (Nakamori).

Such a description is needed for diverse reasons. We feel that the revolutionary change in knowledge creation theories is a sign of the beginnings of a new era of *knowledge civilization* (a broader term than *knowledge-based economy*), and a better understanding of knowledge creation processes is certainly useful for knowledge-based economy, knowledge management, etc. Moreover, systemic models of knowledge creation are useful as a part of new understanding of systems science. Finally, such description can be a starting point of constructing *Creative Environments* – systems supporting creativity.

3. New understanding of systems science

The changes in understanding processes of knowledge and especially technology creation outlined above induce also changes in the role of systems science in the new era of knowledge civilization.

While systems science is by its definition interdisciplinary, a split into *soft systems science* (sociological) and *hard systems science* (technological) developed since a quarter of century ago, see, e.g., [14], [15], [16], [17], [1]. *Soft system thinkers* made an essential contribution by adding *human relation dimension*, based on the correct assumption that diverse aspects of human behavior and human relations cannot be adequately modeled mathematically, thus need essentially different set of systemic procedures and approaches (called by soft systems thinkers, not quite rigorously, *methodologies*).

On the other hand, *soft system thinkers* developed an *anti-hard paradigm* based on a misinformed critique of hard systems science, starting with equating it to operational research as existed a quarter of century ago (while operational research even then was only a part of hard systems science),³ and ignoring the developments of *soft computing* and of *interactive decision support* in hard systems science.

In return, *hard system thinkers*, who define themselves as *investigating mathematical models for diverse ends but mostly for technology creation*, largely ignored the critique by soft systems thinkers feeling that it was unjustified. Thus, a deep disciplinary split developed into actually two separate cultures, illustrating perhaps also the fact that contemporary social science since the time of Marcuse [18] cannot understand technology.⁴ This is very unfortunate, because we need sociology for a better understanding of the new era of knowledge civilization and the era is based on technology creation.

- Social science is committed to its internal problem of stressing the *intersubjective antithesis* to the old Comtian *thesis of objectivity* of sociology. On the other hand, technology needs *informed objectivity* (knowing that absolute truth and precision are not attainable, but pursuing them as useful goals) in order to be successful in the creation of technological

artifacts. Thus, unless and until sociology achieves a *synthesis of intersubjectivity with objectivity*, it will not be able to understand technology creation and problems of the new era of knowledge civilization.

For systems science, however, we must stress that *both hard and soft systems science contributed significantly to the formation of new concepts important for the formation of new era of knowledge civilization*, while the contribution of hard systems science was essential in many aspects – not only as a tool of development of the technological basis for the new era, computer networks and information technology, but also as a source of new concepts essential also for the coming change in philosophy, such as chaos and complexity theory, emergence of qualitatively new properties on higher complexity levels, etc.

- Therefore, also a new integration of systems science is needed, which might be called *informed systems approach*: it should be defined as *the discipline concerned with methods of intercultural and interdisciplinary integration of knowledge, including soft intersubjective and hard objective approaches, open and, above all, informed*.
- *Intercultural* means here respect for cultural diversity, but also an explicit account for and analysis of national, regional, even disciplinary (e.g. *hard* and *soft*) cultures;
- *Interdisciplinary* approach has been a defining feature of systemic analysis for many years;
- *Open* means *intersubjectively pluralist* as stressed by soft systems approach, not excluding by design any cultural or disciplinary perspectives;
- Finally, *informed* means *pluralist and as objective as possible*, as stressed by hard systems approach, not excluding any such perspectives by ignorance or by disciplinary paradigmatic belief.⁵

Such integration is needed because of the demands of knowledge civilization, which requires intercultural and interdisciplinary integration of knowledge. It might be helped by noting the following conclusion from the principle of emergence of qualitatively new properties and concepts at higher levels of complexity of complicated systems, noted in the introduction:

- The emergence principle implies the extension of Boulding's *skeleton of science* [19] as follows: *Beside the biological, human and social levels of systemic complexity, many new levels of complexity of civilization development might emerge*.

To this conclusion, the following three principles of *informed systemic integration* can be attached:

- **The principle of cultural sovereignty:** we can treat all examples of separate levels of systemic complexity as *independent cultures*, and generalize the old basic principle of cultural anthropology: *no culture shall be judged when using concepts from a different culture*.

³ The definition of *hard systems thinking* as sharing the assumption that the problem task they tackle is to select an efficient means of achieving a known and defined end was used by Checkland [14] to prove the *perceived failure of hard systems thinking*. This definition was not recognized by hard system thinkers who say that they use *mathematical modeling of systems for diverse and often unknown ends, including technology creation*. Since *hard* and *soft systems thinking* do correspond to diverse cultures – *technological* and *sociological*, hence defining (based on an inadequate definition), judging and condemning a different culture by *soft systems thinkers* corresponds in fact to one of the gravest sins specified by cultural anthropology – that of *cultural imperialism*. In other words, the right to define what *hard systems thinking* is belongs to *hard systems thinkers*.

⁴ For many decades, social science has been unable to understand technology and its creation. One of the reasons for this unfortunate misunderstanding is the condemnation of technology as a technocratic tool of enslavement – started by [18], followed by [8] and others, expressed by a broad use of the sociological term *the functionalist view of the world* to denote the technological culture. Another reason is that technological objectivism is condemned as an *outdated form of positivistic thinking*; this attitude is strongest in postmodernist and constructivist approaches, but it has been paradigmatically upheld by sociology in general.

⁵ Such as *soft systems thinking* ignores the creative aspects of *hard systems thinking* following its own paradigmatic *anti-hard* belief.

➤ **The principle of informed responsibility:** no culture is justified in creating a cultural separation of its own area; *it is the responsibility of each culture to inform other cultures about their own developments and be informed about developments of other cultures.*

➤ **The principle of systemic integration:** whenever needed, knowledge from and about diverse cultures and disciplines might be synthesized by systemic methods, be they soft or hard, without a prior prejudice against any of them, following the principles of open and informed systemic integration.

Full analysis of these principles and the new corresponding meaning of systems science extend beyond the scope of the paper; see [1] and [20]. Here we apply them to the concept of *Creative Environments*.

4. The concept and types of *Creative Environments*

In the new era of knowledge civilization, given the systemic tools of intercultural and interdisciplinary integration of knowledge, we shall need also *computerized creativity support*. The original concept of *Ba* (see e.g. [21]) denotes place and space in which knowledge is shared, created and used, including *physical* space (offices, buildings), *virtual* space (computer network services), *mental* space (experiences, ideas, emotions). The closest meaning of an English word is *environment*, thus *Ba* can be understood almost equivalently as *Creative Environment*.

However, two essential meanings must be added to the concept of *Ba* in the sense of *Creative Environment*: the *informational technology* meaning and the *social usefulness* meaning. In *informational technology* (telecommunications, computer science and other related fields), *environment* means the context in which information technology is developed: the set of protocols, the operating system, the standard languages used.

➤ Thus, *Creative Environment* has a broad and complex meaning, including the meaning of *Ba*, but for the purpose of this paper is defined as *an informational technology system (software and hardware artifacts) designed to support selected processes of knowledge and technology creation, following the principles of systemic integration outlined above.*

Therefore, we must consider both *soft* and *hard* requirements when developing a *Creative Environment*. For example, the *social usefulness* meaning implies not only the participation of future users in specifying the requirements for such a system, not only its *user-friendliness*, but also following the principle of *user sovereignty* and *cultural sovereignty*, see [1] for details.

We consider thus the challenge of constructing *computerized creativity support* as a part of *Creative Environment*. While there exists some such software systems, e.g. for *architectural creativity*, or for *mind-mapping* or for *brainstorming* support, the development

of such systems should be intensified. Two principles might be used for this purpose:

➤ Firstly, there exists a large experience in *computerized decision support*, and the lessons learned and approaches developed in this field might be usefully adapted to creativity support.

➤ Secondly, typical processes of knowledge creation described in this paper and in [1] might serve as structural models for creativity support.

Knowledge creation processes are extremely diversified and rich. How should we then choose what creativity support should be designed first?

Based on the experiences of decision support, we should not develop any creative support until we specify its functionality with the help of and after consultations with future users – the group of knowledge workers that will actually use the creativity support system. Until creativity support is more developed, however, we must use also other ways.

Second way would be to define selected creativity processes, such as *brainstorming* or *roadmapping* and develop full software packages to support them – see e.g. [13], [22]. We face, however, several dangers on this way: the danger of locking the attention on a creativity theory dear to the software developer, while there are many creativity theories; of not taking advantage of diverse conclusions resulting from the analysis of competitive theories; of indulging in *toolism* (running around with a hammer in our hand and looking where to apply it...).

Third way is to reflect on the variety of knowledge creation theories, select the type of knowledge creation we would like to support, analyze possible creativity processes for this type of knowledge creation, select creative transitions that are judged most important for these processes and finally develop creativity support. If we follow this way, it is also important to concentrate on a group of future users and involve them in all selections and specifications on the way; but we motivate them to be better informed about competitive theories and related choices. Thus, we shall describe this third way in more detail.

We should decide first which general type of a creative process we should support, say, using a logical tree represented in Fig. 3 (although all these processes can be represented in *Creative Space*, for the purpose of selection it is better to use a logical tree).

Let us suppose that we are interested in supporting academic research in its normal (in the Kuhnian sense) type. Than the next choice would be which partial creative process – hermeneutic, as represented e.g. by *EAIR spiral*, or experimental, as represented e.g. by *EEIS spiral*, or intersubjective, as represented by e.g. *EDIS spiral*, we want to support in particular. For example, a material science laboratory might either interested in supporting transitions of *EEIS Spiral*; or, feeling that experimental aspects of knowledge creation are well mastered by the laboratory, might need support, e.g., in hermeneutic reflection, in *EAIR Spiral*.

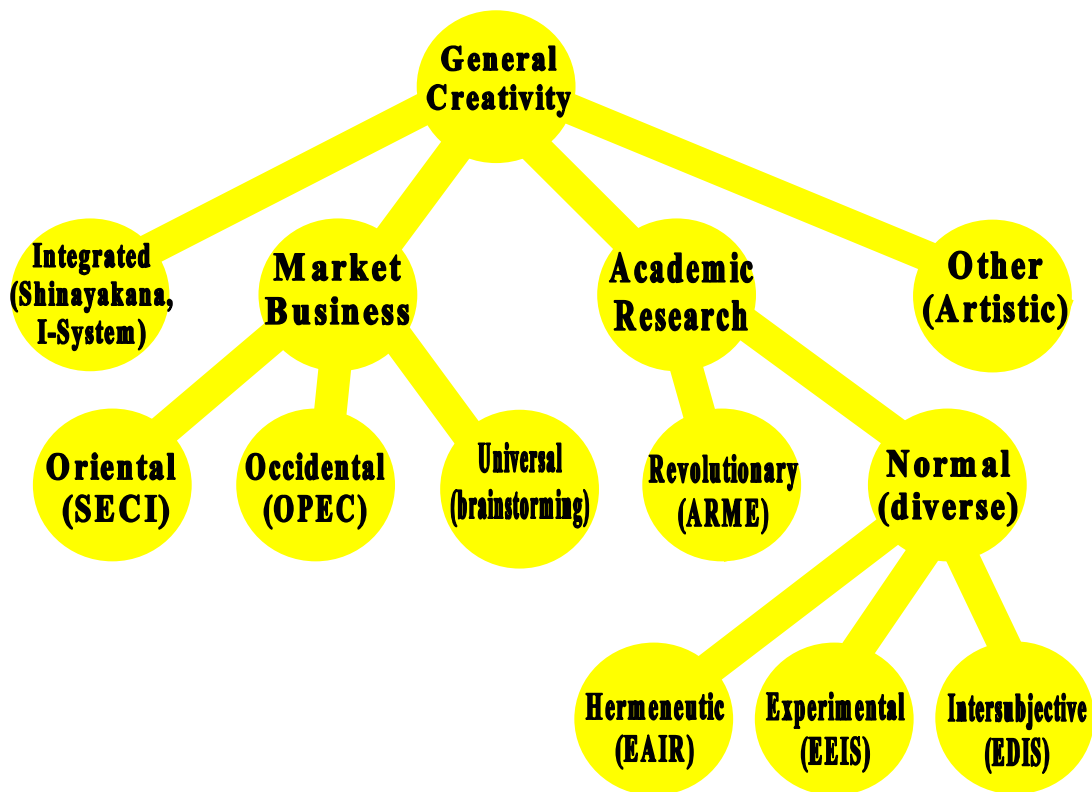


Fig. 3. Logical tree of types of creative processes

In a previous section, we have represented the triple spiral of normal academic knowledge creation as a *Triple Helix*. For the purpose of selection of transitions to be supported, it is good to represent all three spirals of normal academic research on one plane, see Fig. 4. Then we can discuss the meanings of all transitions with future users of creativity support system and ask them for help in selection. We shall shortly comment on possible importance of subsequent spirals and transitions.

The most personal, usually individual creative process is the hermeneutic *EAIR Spiral*. The transition *Analysis* indicates normal research on sources of knowledge: in libraries, through www, at scientific conferences, etc. However, *Analysis* is not restricted to such search; it means also rationally organizing the results of such search, comparing different sources of knowledge, looking for particularly interesting points, etc. This includes methods of finding knowledge relevant for a given object of study in resources available on www; or of using increasingly frequent electronic access to classical scientific libraries. There are many other possibilities for supporting this transition.

Next transition, *Hermeneutic Immersion*, means letting the results of *Analysis* become integrated with all our experience and knowledge of the subject, immersed into our deep memory, into unconsciousness and intuition. This immersion can be of two types: *Critical*

(which means being critical about the object of study) or *Integrated* (which means trying to empathize with the object of study, e.g. imagining ourselves being a car if we study a car). This immersion requires some time to reach into our unconscious intuition, but is necessary to prepare a deep *Reflection*, enriching the individual intuition and leading to *Enlightenment* – new ideas about the object of study (which is actually also the starting transition, because we cannot search without an initial idea). The quality of *Reflection* is shown in the quality of ideas generated in the *Enlightenment* phase.

This process illustrates the difficulty of computerized support of partly or fully a-rational transitions: how to support *Hermeneutic Immersion* or *Reflection*? We cannot support them directly, but we can design such support for the *Analysis* transition that takes into account and makes easier the subsequent transitions. The computerized support for *Analysis* should be as much *interactive* as desired for expressing aspects of *Analysis* that are intuitively important for *Hermeneutic Immersion* or *Reflection*.

The hermeneutic *EAIR Spiral* is typical for research in arts and humanities, more important for these fields than even the intersubjective *EDIS Spiral*. However, creating technology is essentially an art; thus, it is very useful to adopt *EAIR Spiral* also for technology creation. In this case, naturally, it should be used to augment the

experimental *EEIS Spiral* and the intersubjective *EDIS Spiral*.

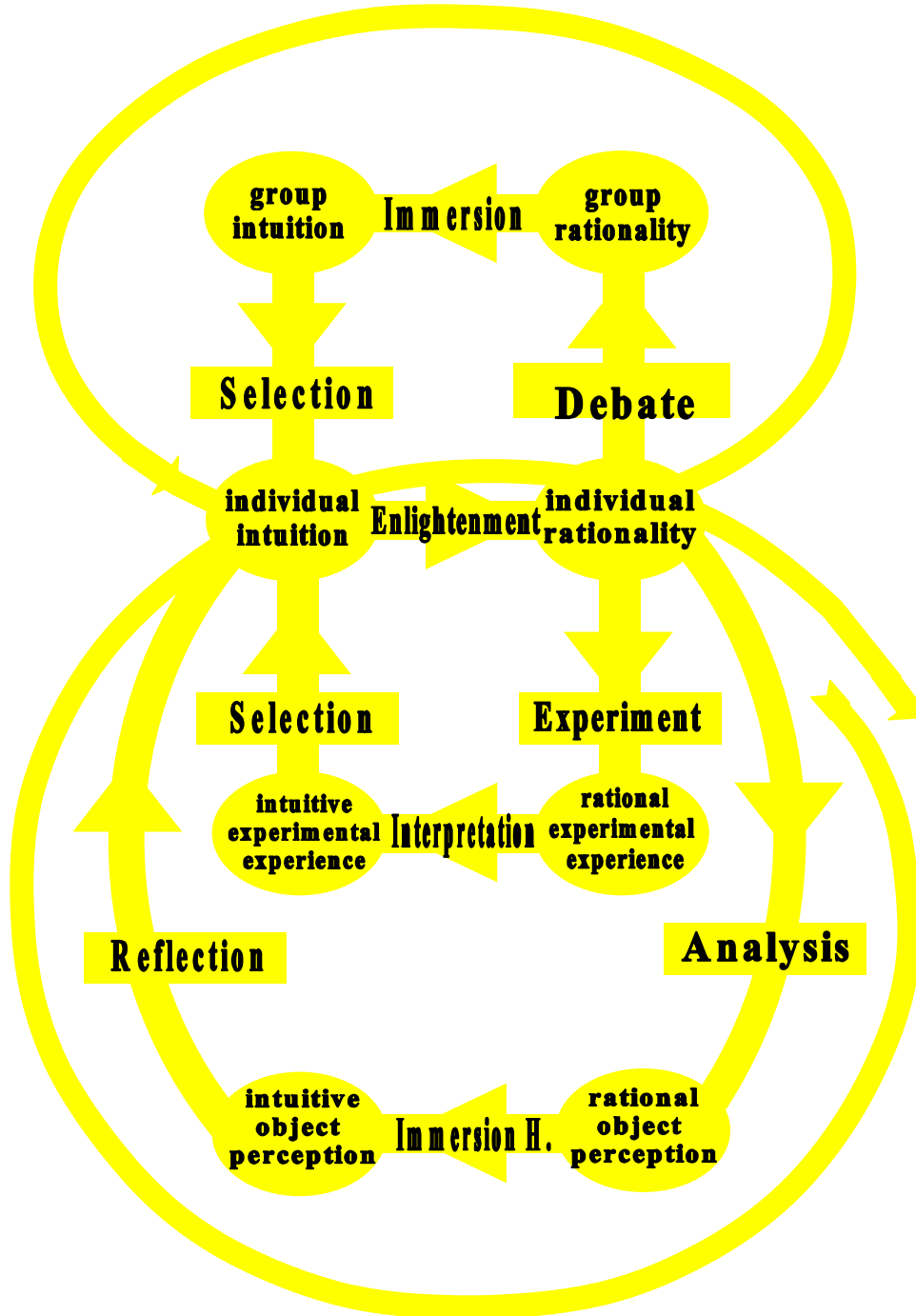


Fig. 4. The Triple Helix projected: the EAIR-EDIS-EEIS Triple Spiral of normal academic knowledge creation

The experimental *EEIS Spiral* is typical for hard sciences and technology development, although sometimes also used in experimentally oriented social sciences. After having an idea as a result of the *Enlightenment* phase, the researcher wants to test it

experimentally. This is done in the phase *Experiment* but is not necessarily a simple issue. Most experiments are individual, but some require group support; even if the experiment is individual, it requires good *experiment design*. There exists quite advanced statistical theory of

experiment design, see e.g. [23], that can be used to support experimental creativity. Another aspect of experiments that can be supported is the possibility of preparing *actual experiments* with help of *virtual experiments*, computer simulations that might help to limit the need of multiple experiments to a few crucial ones. A great challenge for future creativity support is using modeling resources for building *virtual laboratories* capable to support diversified virtual experiments.

After experiment, the researcher evaluates and interprets the experimental results. There are diverse statistical techniques (of regression and factor analysis, etc.) accompanied by various techniques of graphic representation of results for supporting *Interpretation*. But it must be remembered that *Interpretation* is a partly a-rational transition, hence these techniques play important, but only supportive role. Finally, *Selection* is a deeply individual, intuitive and fully a-rational process of choosing such aspects of interpreted experimental results that serve best for a new *Enlightenment*.

The intersubjective *EDIS Spiral* can be used in any field of knowledge creation – in arts and humanities, in social sciences, in hard sciences and technology, being the basic way of verifying newly created knowledge through *Debate* inside a group. The use of this spiral depends very much on the traditions of the group and of the scientific discipline: some prefer to have a *Debate* in very early stage of research, some fear presenting an idea before it is fully tested either in a hermeneutic or experimental way. From the point of view of stimulating creativity, *Debate* is useful at every stage of research – in the beginning, in the middle, but certainly needed also at the end.

The principle is the same in all stages: it is the responsibility of the group, in the best old university tradition, to give a good, critical but also empathic, *Debate* to any of its members presenting some new ideas for an intersubjective verification; see [1] for the description of diverse aspects of a good *Debate*. However, *EDIS Spiral* stresses also some novel aspects, related to *Rational Theory of Intuition*: it suggests organizing a second part of the *Debate* after the participants achieved *Immersion* of the results of the first one into their intuition, which constitutes the *Principle of Double Debate* [1]. Again, *Selection* is a deeply individual, intuitive process of choosing such aspects – this time of conclusions from the *Debate* and possibly from *Double Debate* – that helps best in developing new ideas in the repeated *Enlightenment* phase.

The fundamental transition for all individual spirals in the *Triple Spiral* is *Enlightenment*. It is called alternatively *illumination*, *aha*, *heureka*, but denotes having an idea (bigger or smaller), generating it from unconscious, intuitive knowledge. This transition can be supported by *Reflection* in *EAIR Spiral*, *Debate* in *EDIS Spiral*, *Experiment* in *EEIS Spiral* etc. It has an intrinsic individual character, though it can be also supported by

diverse group processes, such as *Debate* or *Brainstorming*.

However, the essential point is that unconscious intuition requires time for preparation of new ideas, for *gestation of the idea*, which can be stimulated by *forgetting the problem*, *sleeping with the problem*, *emptying your conscious mind*, *forgetting the prejudices of an expert*. Thus, any technique of creativity support should take into account support of gestation, but can support it only indirectly. There are two types of such support: one is simply including relaxation (e.g. *going to a tea ceremony*) into plans of creative processes, e.g. in *Roadmapping*; another is supporting indirectly – e.g. also by the correct organization of the creative processes – these phases or transitions that precede *Enlightenment* and help in gestation. These are the transitions of *Immersion* and *Selection* in *EDIS Spiral*, the transitions of *Interpretation* and *Selection* in *EEIS Spiral*, the transitions of *Hermeneutic Immersion* and *Reflection* in *EAIR Spiral*.

But such indirect support of gestation might be different in different processes. In *EDIS Spiral*, it means simply repeating the presentation and debate after some time, according to the *Principle of Double Debate*: giving enough time for gestation of ideas triggered by first debate, not too long such that the subject is not entirely forgotten, and then organizing second debate. In *EEIS Spiral*, it means making breaks between subsequent experiments; sometimes they follow naturally from the necessity of setting up new experiments. In *EAIR Spiral*, which is the most personal of spirals of normal knowledge creation, it means creating conditions for good *Hermeneutic Immersion* – relaxation after individual studies of scientific literature, after searches in human rational intellectual heritage, letting your unconsciousness work before starting essential, intuitive *Reflection*.

After such analysis of the *Triple EAIR-EDIS-EEIS Spiral* of normal academic knowledge creation, how should we decide on which parts of it should we concentrate in developing creativity support system? A natural answer is: by asking the future users of the systems, constructing an appropriate questionnaire – or a sequence of questionnaires – and evaluating the answers.

Until such a demand analysis is done, however, we can identify several types of needed *Creative Environments* by the intensity of known research on such topics, responding to clearly perceived needs. By applying this method, we identified the following needs:

- *Web knowledge acquisition*,
- *Debating*,
- *Experiment design and support*,
- *Virtual laboratories*,
- *Road-mapping for scientific research*,
- *Brainstorming*,
- *Gaming for creativity support*,
- *Electronic and distant teaching and learning*,
- *Innovation in modern small enterprises*.

For more detailed comments on these needs see [1]. Here we give only short comments on *electronic and distant learning and teaching*.

Although learning and teaching is usually treated separately to knowledge creation, we should stress here that innovative learning and teaching also requires creativity. In [1] we have postulated a basic education reform, involving the use of computer networks and electronic distant teaching forms to support education in developing countries. However, electronic distant learning materials are developed, until now, on case-to-case basis, no standardized *environment* for creating such materials is available. Thus we need the development of *Creative Environment for Distant Learning and Teaching Materials*, well provided in software tools for creating such materials, but also in methodological background.

5. Conclusions

The purpose of this paper was to recall recent results – see [1], [2] – on *Creative Space*, a metamodel of creative processes of knowledge and technology, as well as on new principles of systemic integration, in order to further develop the concept of *Ba*, or a *Creative Environment*, interpreted here as an informational technology system (software and hardware artifacts) designed to support selected processes of knowledge and technology creation. The main result is the specification of types of *Creative Environments* that need most attention and development.

As indicated earlier, one of basic conclusion concerning computerized *Creative Environments* repeats the experiences from applying computerized decision support: such environments cannot be developed in abstraction, must involve future users in a careful and deep debate of their essential needs and requirements, in specification of the functionality of such environment with the help of and after consultations with the group of knowledge workers that will actually use the creativity support system. This should not be, however, a one-directional communication: before specifying the functionality, the future users must be well informed about the possibilities of this new type of software systems.

Thus, we tried to outline here the possibilities of the development of *Creative Environments* going beyond the already fast development of computer graphics for artistic or architectural creativity and including diverse activities and processes of knowledge and technology creation, such as knowledge acquisition, debating, experiment design and support, virtual laboratories, roadmapping, brainstorming, gaming, distant learning and teaching.

A general conclusion is that the development of *Creative Environments* is a big challenge; this challenge, however, must be addressed during the development of knowledge civilization.

Bibliography

- [1] Wierzbicki, A.P. and Y. Nakamori 2005, *Creative Space*. Springer, Berlin
- [2] Wierzbicki, A.P. and Y. Nakamori, *Knowledge Creation and Integration: Creative Space and Creative Environments*. In Sprague, R.J. (ed) *Proceedings of HICSS 38*, IEEE Computer Society, Los Alamitos, Ca
- [3] Nakamori, Y. and Y. Sawaragi 1992, *The Shinayakana Systems Approach to Decision Support*. X-th MCDM Conference, Taipei
- [4] Nonaka, I. and H. Takeuchi 1995, *The Knowledge-Creating Company. How Japanese Companies Create the Dynamics of Innovation*. Oxford University Press, New York
- [5] Wierzbicki, A.P. 1997, On the Role of Intuition in Decision Making and Some Ways of Multicriteria Aid of Intuition. *Multiple Criteria Decision Making* 6, 65-78.
- [6] Motycka A. 1998, *Nauka a nieświadomość* (Science and Unconscious, in Polish). Leopoldinum, Wrocław
- [7] Nakamori, Y. 2000: Knowledge Management System towards Sustainable Society. *Proceedings of First International Symposium on Knowledge and Systems Sciences*, pp. 25-27.
- [8] Habermas J. 1987, *Lectures on the philosophical discourse of modernity*. MIT Press, Cambridge MA
- [9] Polanyi, M. 1966, *The Tacit Dimension*. Routledge and Kegan, London
- [10] Gasson, S. 2004, *The Management of Distributed Organizational Knowledge*. In Sprague, R.J. (ed) *Proceedings of HICSS 37*, IEEE Computer Society, Los Alamitos, Ca
- [11] Wierzbicki, A.P. and Y. Nakamori 2004, Creative space: a tool for knowledge integration. *International Journal for Knowledge and Systems Science* 1:26:32
- [12] Qureshi S. and P. Keen 2005, *How to overcome the knowledge paradox: activate knowledge identity, not just organize information*. In Sprague R.J. (ed) *Proceedings of HICSS 38*, IEEE Computer Society Press, Los Alamitos, Ca
- [13] Kunifujii S. 2004, *Creativity support systems in JAIST. Proceedings of JAIST Forum 2004: Technology creation based on knowledge science*, pp 56-58
- [14] Checkland P.B. 1978, The origins and nature of “hard” systems thinking. *Journal of Applied Systems Analysis* 5: 99
- [15] Jackson M.C. 2000, *Systems approaches to management*. Kluwer Academic - Plenum Publishers, New York
- [16] Midgley, G. 2003, *Systems Thinking*. SAGE Publications, London
- [17] Lucertini M., A.M. Gasca, F. Nicolo 2004, *Technological concepts and mathematical models in the evolution of modern engineering systems*. Birkhauser, Basel
- [18] Marcuse H. 1964, *One-dimensional man*. Beacon Press, Boston
- [19] Boulding K. 1956, General systems theory – the skeleton of science. *Management Science* 2: 197-208
- [20] Wierzbicki A. 2005, *Technology and Change: The role of Technology in the Era of Knowledge Civilization*. The First World Congress of International Federation of Systems Research, Kobe
- [21] Von Krogh, G., K. Ichijo and I. Nonaka 2000, *Enabling the Knowledge Creation*, Oxford University Press
- [22] Ma, T., S. Liu and Y. Nakamori 2004, Roadmapping for supporting scientific research. *Proceedings of MCDM 2004*, Whistler, Canada, Simon Fraser University
- [23] Tsubaki H. 2005, The grammar of technology development: fundamental strategy. *Proceedings of International Workshop on The Grammar of Technology Development*, University of Tsukuba Tokyo Branch