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The problem of the problem in inventive activity

Some prominent researchers of creativity regard “the problem of the problem”, that is, the finding and definition of important problems, as a key phenomenon of the creative process (Getzels & Csikszentmihalyi 1976; Getzels 1982 and 1987). Getzels cites Einstein who stated that the formulation of problems is often more essential than their solution (1982, 37): “To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science.” Therefore, instead of the problem-solving process, creativity research should focus on how important problems are being found and formulated (Getzels and Csikszentmihalyi 1976, 81):

> “The problem solver must become a problem finder (….). To turn a problem solver into a problem finder one must feel that there is a challenge needing resolution in the environment, one must formulate this feeling as a problem, and then attempt to device appropriate methods for solving it (…) Not only the solution but the problem itself must be discovered.”

Getzels rightly points out that the world is teeming with conflicts and dilemmas. However, they must be specified and formulated in fertile and radical ways if they are to be moved to productive termination (Getzels 1982, 38). An important and fruitful problem is open to resolution and leads to a line of inquiry in the inventive activity. A German researcher Rainer Seidel (1976) has proposed that to solve the problem of the problem a social history of problems is needed. The tensions and contradictions of human practices are the starting point for the creation of new artifacts and methods. Seidel himself studied the emergence and early development of the steam machine. He shows that the practical problem that inspired James Watt to improve the steam machine was the water problem in the coal mines of England. A more efficient power machine for the pumping devices was in urgent demand. According to Seidel, the process of problem solving can be analyzed as a series of reformulations of the original problem, an economic and practical inadequacy of an activity.

The historians of technological systems have developed the idea of critical problems of the technical or sociotechnical system as the source of technological change and inventive activity. Thomas Hughes has used the term *reverse salient* to refer to the weakest point in an expanding technological system (1988, 80): “An analysis of a growing system often reveals the inefficient and uneconomical components, or reverse salients.” His studies on American inventors show that they applied themselves to solve critical problems inherent in reverse salients. Edward Constant has regarded *functional failure*, a system's inability to function in new and more demanding circumstances, as a major impetus to technical change (Constant 1984, 648). An economic historian, David Rosenberg, has shown that local activities using the same kind of technology, making the same kind of processes and living in a shared market environment face the same kind of problems. Rosenberg studied the history of machine tool industry in the U.S.A (1963, 423):

"It is because these processes (such as drilling, turning, boring, ect, R.M) and problems became common to the production of a wide range of disparate commodities that industries which were apparently unrelated from the point of view of the nature and the uses of the final product became very closely related (technologically convergent) on a technological basis, for example, firearms, sewing machines, and bicycles."

This “universality” of the problems also constitutes the basis for the recognition and diffusion of an innovation (Rosenberg 1963).

In addition to reverse salient, Hughes also uses the concept of the *critical problem*. According to Hughes, critical problems can be defined as problems retarding technological/or industrial change and as problems likely, in the opinion of inventor, to be solved by invention (Hughes 1978, 172). He understands that critical problems constitute a bridge between the imbalances of current technology use and inventive activity. The formulation of a critical problem already implies the possibility and direction of the solution. (ibid.):

“Possibly the identification of a critical problem should be placed not only in the ‘problem identification’ category but also in ‘idea generation’, for the identification itself is an act of insight, probably not unlike idea response. Defining the problem is a big step along the route to solution.”

Hughes delineates a logic of problem finding and idea formation in an inventive activity.[1] The first four phases of this logic are: 1) *Problem identification*, which includes the identification of the reverse salient and its transformation into a critical problem.2) *Idea response* that includes information

[1] Hughes constructs this logic in analyzing historical cases of inventors’ activity (1978, 180): “The exploration of case histories .. that analytical interpretation does bring credible – and not simplistic – order out of a chaos of facts.” This attitude corresponds with what Marx Wartofsky thinks about the possibility of a logic of discovery. Such a logic does not supply an explanatory theory of invention, but,

gathering, searching for concepts and an analysis of prior solutions and their week points. 3) *Invention*: finding a principle of a new solution and giving the first idea a form, for instance, as a drawing, 4) *Research and development* toward facing the complexity of user environment. This involves testing and leads often to the redefinition of the problem and to new ideas that increasingly meet the demands of the user environment.

This logic has affinities both with Seidel and with the logic of problem solving of John Dewey. In Dewey's logic, the five steps are (Dewey 1938/1991,105): 1) an indeterminate situation: the established way of doing things does not work, 2) intellectualization: defining the problem, 3) study of the conditions of the situation and the formation of a working hypothesis, 4) reasoning: testing the hypothesis in thought experiments, and 5) testing the working hypothesis in action, that is, by putting it into practice. All the three models imply the transformation of a practical-economic problem into a technical (critical) problem and, further, into the first idea of a solution (a working hypothesis).

Two theories of human practice, cultural-historical activity theory and Deweyan pragmatism, regard change in human activities as a basis for creation and retooling. Because of the change, also the instrumentalities of activity are condemned to advance (Dewey 1909/1977, 6). Activity theory has analyzed the internal contradictions of activity systems as a source of development (Engeström 1987). These developing contradictions first express themselves as errors, disturbances and as indeterminate discontent, that can be called a need state. Transforming them into a recognized problem, requires conscious reflection by the participants (intellectualization in Dewey). The conception of historically emerging contradictions resembles the thesis of the historians of technology of the critical problems as the source of technological change. This is not surprising, owing to the fact that the

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rather, a suggestive logic (1980, 15): "an account of examples, of actual exercises in judgement given specific boundary conditions, or problem situations, or a reconstruction of historical cases".

concept of a sociotechnical system has affinities with the concept of activity: it implies the activities of production and use of technological artifacts.[2]

The problem of the problem in the invention of Delfia technology[3]

Immunodiagnostic methods are used in the diagnostics of illnesses and dysfunctions of internal secretion. The methods rely on utilizing antibodies, the function of which in the human body is to recognize a foreign substance or agent - called an antigen - fasten to it and make it inactive. Antibodies recognize different antigens very selectively. By marking the antibody with a proper label substance, the quantity of the antibody-antigen complexes in a specimen can be measured

In the 1950s, a new immunodiagnostic method, radioimmunoassey (RIA) was launched. In it, antibodies were labeled with radioactive isotopes. The RIA was far more sensitive and quicker than the biological methods used before in diagnostics. In the 1970s, a small Finnish enterprise, Wallac, a manufacturer of measurement devices of radioactivity, developed an alternative immunodiagnostic method where radioactive labels were replaced by fluorescending compounds. The new product, under the trademark of Delfia, was introduced to the market in 1984. The idea had first been formulated in Wallac in 1974. The discovery changed Wallac from a producer of measuring instruments into a producer of immunodiagnostic kits.

Wallac was founded in 1950. In 1960, Dr. Soini was recruited as the research manager of the company. In the late 1960s, new alfa- and gamma calculators for the measurement of radioactivity were launched to the market and they constituted the main product of Wallac until the 1980s. The calculators were produced for multiple purposes. Dr. Soini tells:

"First we manufactured general purpose gamma calculators. RIA was only one application among many. In those days I didn't know anything about RIA. After more devices were sold to immunodiagnostic laboratories we got interested and established contacts with them" (Interview of Erkki Soini, 12.3.1999).

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[2] Hughes uses expressions like (1978, 172) "Advancing technological, economical and social systems have reverse salients, bottlenecks and imbalances calling for response"

[3] The analysis presented here of Wallac is based largely on an account "Delfia – a revolt in immunodiagnostics" written by Jukka Hyvönen and Reijo Miettinen and published in Finnish in Miettinen & al. 1999, 117-144 and in Miettinen 2000.

The most important collaborative relationship was established with Professor Roger Ekins from the Middlesex Hospitals Medical School located in London. Ekins was one of the developers of RIA. His laboratory was the first in Europe to use immonodiagnostic methods. Ekins had bought the gamma calculator of Wallac in 1971, and representatives of Wallac had visited the London laboratories. A relationship of collaboration and friendship was formed between Dr. Soini and Prof. Ekins. They developed together gamma-calculators for RIA. Professor Ekins recollects:

"I was invited to visit Turku … They (Wallac) wished me to provide knowledge of the requirements radioimmunoassay poses to the calculator and they also wished more general knowledge of the development of the radioimmunoassay" (Statement by Pof. Ekins 2.3.1994).

Wallac designed a gamma-calculator specifically for RIA. It came to the market in 1976. During the collaboration in the early 1970s, Soini gradually learned that RIA has also several limitations, which, as a matter of fact, constrained the development of immunodiagnostic methods. The sustainability of radioactive labels was bad, often from six to eight weeks. They were awkward to handle and involved health risks requiring special safety equipment, and after use became problem waste. Dr. Soini recollects how he saw the situation (Interview 12.3.1999):

"It was already clear, that the use of radioactive labels in chemistry and biomedical research was difficult, because the researchers couldn't use them freely. They always had to go to a laboratory that was inspected and ratified; There were systems of control, and so forth. It was clear, that had it been possible to use these methods without radioactivity, their use would have expanded, and so would the market, of course."

This statement includes a description of the reverse salient of the immunodiagnostic testing practice and its transformation into a critical problem to be solved: "had it been possible to use these methods without radioactivity, their use would have expanded, and so would the market, of course." The dilemmas of RIA use were, of course, well known to practitioners, but, as long as RIA was the most sensitive method - and the only possible one for several applications - and was no alternative method in sight, the disadvantages were taken as a necessary evil and as belonging to the state of art by the practitioners. To transform them into a viable problem required a perspective of an alternative. Soini's perspective held a vision of the forthcoming development of immunodiagnostic testing and a possibility of business activity attached by it. It combined the perspectives of the testing activity and the production of test kits.

A critical problem formulated already calls for the direction of the solution. At the time Soini started to think of an alternative method, enzymes and fluorescent labels had been presented in the literature as potential alternatives for radioisotopes. By 1974, Soini was convinced that the solution should be based on fluorescence. The first working hypothesis, or a guiding idea for the inventive activity, an idea of a new product, was formed: by replacing the radioisotope by fluorescent label, the reverse salient of immunodiagnostic testing could be resolved and, and a new market created for Wallac, whereto expand its business activity.

The subsequent development of the first generative idea for an alternative immunodiagnostic method follows fairly well what Seidel and Hughes propose. A reverse salient, or a practical or economic inadequacy, is transformed into a technical problem calling for a solution. The general direction of the solution figures out as a guiding idea or a working hypothesis. Thomas Nickles contrasts this kind of appraisal to epistemic one. The latter is retrospective, whereas heuristic appraisal is forward-looking following more the logic of promise and fertility than justification (Nickles 1989). In the case of technologies, “fertility” or “objective promise” is grounded on a realistic recognition of the reverse salients of a practice. This grounding is likely to take place in the producer-user relationship (Lundvall 1988) actualized in face-to face communication and in visits to each other’s working sites. The general idea of an alternative immunodiagnostic method based on the use of fluorescence has a technical form. It is, however, entirely open-ended: all the more concrete solutions to the basic elements of the forthcoming system are open. Each of them will form a more specific task and a problem with a corresponding, more detailed hypothesis. The concretization of the first idea forms, therefore, a process composed of a series of partly successive, partly intertwined problem-solving cycles.

Conclusions

In the case of Delfia, the formation of the first idea leading to the development of the method took place in several discussions between Dr. Soini and Prof. Ekins, as well as other users or RIA. The reverse salient is about the hindrances of the expansion and development of a practice, in this case immunodiagnostics. It is evident that this knowledge of the dilemmas and developmental possibilities of the practice come from Prof. Ekins and other practitioners. This is what Soini himself tells (Virkkunen 2000, 21):

“Prof. Ekins tried hard to teach us what radioimmunoassay is and what it requires. We didn’t understand very much about radioimmunology at that time (…..) A normal hospital chemist wouldn’t have realized the future, which Ekins was able to see. These advises were worth millions. Had you put some market man to conduct a market study, the verdict would have been: there is no need or demand.”

This corresponds with what Von Hippel (1986) found in his studies on the sources of innovation and what he suggests about learning from lead users. On the other hand, Dr. Soini’s knowledge and expertise in developing measurement equipment enabled him to transform the problem into a vision of an alternative method realizable by inventive work. This amounts to what Wartofsky calls (1980,14) “practical imagination – the capacity to invent alternative modes of action in terms of present possibilities and conditions; or capacity to invent new conditions beyond present limits”. The case strongly supports the idea, that “hybrid interaction” across the boundaries constitutes a transepistemic arena which makes the exercise of such an imagination probable. It is a way of getting the distributed heterogeneous cultural knowledge and resources to interact in a synergic way favorable to the formation of new ideas.

How should then, the significance of individuals be understood in the process? I believe that the importance of Dr. Soini’s contribution for the practical accomplishment of Delfia is without question. His tireless organizing perseverance was decisive for the inventive work. In the first years of the process, Wallac and its owner company Pharmacia did not support the project. Soini had to advance without support from his organization and without any significant funding. Soini was, therefore, the “champion” or innovator suggested by innovation literature as a key factor in the success of an innovation process. He might also be thought of as such an innovator, as delineated by actor network theory, who translates the interests of others to make them contribute to the work of construction (Latour 1987). This work of mobilization was an aspect of his work but, if taken alone, does not make justice to the nature of the interaction of the process.

In his accounts of the process, Soini repeatedly characterised what he learned from others: the idea itself and basic elements for the solutions were formed in interaction. In constructing himself as an inventor, he simultaneously acknowledged the deeply distributed nature of the invention process. In his accounts, he gives without hesitation credit to others as sources of ideas, visions, important pieces of knowledge, suggestions and for their capabilities of doing the necessary experiments. Still he maintains that it was his vision: he put it into realization by his perseverance. His account of himself as an innovator is indistinguishable from his interaction with others and their cultural resources. This corresponds with what Hélène Mialet (1999) called a distributed-centered conception of subjectivity.

Is there any sense in trying to construct a logic or a methodology of invention? When Marx Wartofsky discussed the problem (1980, 15) he stated that such a of logic could only be a suggestive logic based on the reconstruction of the practice of creation which makes learning from the historical cases possible. Because the nature of inventive and creative practice itself is changing, case studies on different levels can help us understand in a richer way the diverse aspects of inventive activity. Consequently, the attempt to analyze the social and distributed nature of inventions, is not inspired by theoretical reasons only. It also springs from the changing nature of the inventive activity itself.

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