INNOVATICS – A NEW TOOLBOX OF SKILLS FOR INNOVATIVE PRODUCTION MANAGERS

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Summary: We describe a metaphorical "toolbox" for innovatics – a new set of skills for managers who specialize in innovation management and in the study of innovations. We emphasize the importance of quantitative skills, multidisciplinary inspirations and heuristic methods for generatig innovative solutions. Knowledge of organizational behavior is essential to create in the workplace environment conducive to innovativeness.

Keywords: cooperation, creativity, innovation, quantitative methods, scientometrics.

1. Innovatics: a new discipline?

Innovativeness enables one to create something from nothing. A fleeting dream-like idea changes into innovation. However, the time of romanticism in innovation, when new horizons were opened and new niches were created by inventors who had no specialized education, is already over. The standards have gone up. One could say that the low-hanging apples are already picked, and those that were supposed to fall on the heads of Newtons sitting under the apple trees – already did. We argue that managers cannot hope to become innovative by luck, but must become skillful in innovatics.

Innovatics is a new term which is introduced to emphasize the challenges originating in the modern social and economic reality. This is the world of connectedness, of vast and easily accessible databases, of open borders and of the butterfly effects [1]. The latter means that most distant and local phenomena may be connected through seemingly weak indirect links, when a trivial change in one phenomenon may generate unexpectedly powerful nonlinear cascades of remote effects.

In this reality, innovations are the fuel of technological and social progress [2; 3]. They spread on networks [4; 5] and development feeds on innovations which are the basic building blocks of economic life. This is why innovativeness is important and we must know how not only to manage it, but also how to study it and how to discover laws which govern it. We suggest that innovatics has a broader scope and requires a wider range of skills than the traditional innovation management.

The purpose of this text is to explore the following issue: how should we teach innovative managers to prepare them for work in industry [6]? This is a special case of a challenge of teaching innovative thinking [7] or adding practical relevance of production management topics to college curricula [8; 9]. E-learning could also become an effective and satisfactory method, e.g. in teaching of industrial engineering students, if certain conditions (such as a right mixture of human interaction and IT) are met [10]. Even traditional MBA programs are being re-examined [11; 12], and may evolve away from classroom-based analyses of cases, towards interdisciplinary experience, mentoring for managers, or "boot camps" for entrepreneurs [13].

Such managers should be capable of organizing, developing and expanding innovative workplace, e.g. avoiding artificial and incorrect separation between the sites of innovation and production [14]. However, the notion of an innovative workplace could have two meanings, or, by analogy to the well-known concept of the leadership grid [15], two dimensions. First dimension concerns the human perspective – corresponding to the "employee-oriented" leadership styles. Second dimension ("task-orientation") describes the innovativeness of the process of production itself.

What skills should we then equip managers with if they are expected to be innovative? Being innovative requires from the manager broad interests, universally-applicable skills and cutting-edge knowledge. Below, we will try to describe some tools from a dream "toolbox" of innovatics, which any innovative production manager should have at his/her disposal in the second decade of the 21st century [16].

2. Innovatics' toolbox: organizational behavior

The workplace to form environment conducive to innovativeness (with the proposed acronym: ECTI) should possess certain characteristics [17]. It should be:

- stress-free and peer-pressure-free, because employees are easily intimidated and embarrassed, when their contributions are expected to be non-standard or novel;
- hierarchy-free, because employees perform better and their spontaneity is improved when formal relations among them are minimized rather than emphasized;
- routine-free, suspenseful and fun, because people are easily bored, enjoy being spontaneous and tend to be more creative when they are playful;
- stimulating by providing immediate feedback and hints, because people are impatient and adding a sense of urgency has a beneficial effect on the creative process;
- orderly, because providing easy access to fact checking facilitates idea evaluation by removing ambiguities or imprecision. "Creative chaos" is beneficial only if it is under control.
- interdisciplinary, because providing inspiration from other disciplines may generate the beneficial effect of "consilience" [18].

The basic condition which must be fulfilled for the human potential of the employees to be fully utilized is strengthening the social capital. Organizational culture which is based on mutual understanding, reciprocity and trust, naturally leads to innovativeness [19; 20]. Robert Axelrod's [21] theory of cooperation explains not only the underlying logic of human trust, but yields specific and practical recommendations as to how to build it and maintain it. It may translate into effective sharing of tacit knowledge between managers and employees, as shown e.g. by Muniz et al. in the shop floor environment [22].

There is also an important side to innovativeness: we tend to be naturally reluctant to accept change, and innovation, by definition, means an introduction of change [23]. A sense of threat to the employees' status quo is implicit in any change and managers must skillfully and convincingly "sell" the logic and necessity of innovative modifications to employees. Such managerial "soft skills" are difficult to master, since they are based on human interactions, and shortcuts usually do not work.

One of the practical aspects of creating ECTI is building balanced and innovation-oriented teams and it should start from taking into account proper representation of team roles, for example, using the categorization developed by Belbin [15]. Educational level and composition of top management teams also impact innovation performance of firms [24]. Statistical analyses (also with comparisons among countries) document that there are indeed positive causal links between creativity and leadership styles, supportive types of relationship between employees and management [25], and increased diversity of knowledge among employees [26].

3. Innovatics' toolbox: psychology of creativity

We believe that it is possible to train employees to be more creative [27], although there are many obstacles, e.g. collaborative creativity [28], when students or employees simply do not know how to share ideas and participate in group debates during team-based innovation projects [29].

On one hand, creativity is improved by ecclectic inspiration, i.e. seeking inspiration by studying examples of creative problem-solving in other disciplines, such as science, art, literature, and industrial design. On the other hand, one must remember about limitations on creative freedom that exist in applied disciplines. For example, development of an innovative product must take into account the requirements of ergonomics – and by this we mean both traditional ("tangible") products and software [30]. In the latter case, traditional recommendations based on human physiology and biomechanics are replaced by the rules of cognitive psychology, which govern our interactions with the functionalities of software. Proper design of the manufacturing processes should obey the same rules, including the most powerful of them all, epitomized in the title of the classic book on web page design: "do not make me think" [31] – knowledge management calls this feature of the production process "transparency" [32].

There is a rich array of methods aimed at supporting problem solving and generation of innovative solutions [33]. They include group-based methods, such as the classical brainstorming, six thinking hats by Edward de Bono [34], nominal group and Delphi method, and also approaches useful in the context of individual work, such as Altshuller's TRIZ algorithm. Such heuristic methods are universal, i.e. can be applied in the most diverse aspects of life, and this makes them worth studying and incorporating in everyday practice of managers. Many of these methods have been created to neutralize the errors of our, so called, common sense, revealed in the last decades by research in economic psychology (including behavioral finance), cognitive psychology and evolutionary psychology.

4. Innovatics' toolbox: multidisciplinary inspirations

Innovative manager should look for inspiration in areas other than his/her area of technical expertise, but always staying in touch with the needs of the industry [13; 35]. Radically new ideas and novel solutions to old problem reside in the zone of influence of many disparate disciplines [36]. We believe that synergy arising from combining technology and biology will create the next Brave New World. We are not suggesting that seeking multidisciplinary inspirations is relevant only to entrepreneurs who design new products. Process-oriented managers who see the production processes implemeneted in their plants in a new light, may introduce fundamentally new ways of e.g. exploring designs for alternative production lines and planning of factory layouts.

Very fundamental conceptual revolutions may occur through applying scientific concepts developed in completely different fields. For example, formulating the basic best practices of production [reduction of cycle time, reduction of variability, increase in transparency, and continuous improvement of the process) and the powerful metaphor of the flow (characterized by phases of waiting, transporting, inspecting, and processing)[32] may stimulate us to seek inspiration in other fields. Metabolic flux theory in biology is a potential source of useful insights for production management theory since it also deals with processes of flow (of substrates, products, energy etc.).

In thinking about modularity, an important paradigm in design of complex systems (applicable to production systems, organizations, or products) [37], we should seek strong parallels in theoretical and developmental biology, since many biological systems have modular organization. A recent concept of factory fitness, rather than leanness in production [38], has very strong resemblance to viewing the functioning of a living organism, with physiological process that can be optimized. Similarly, introducing Darwinian biology and evolutionary psychology to organizational behavior may help managers design more effective human resource management procedures [39; 40].

5. Innovatics' toolbox: information science and scientometrics

Managerial skills of effective searching the databases, such as ISI Emerging Markets (database of economic information) lub EBSCO (scientific database) should be now taken for granted. It is impossible to imagine that one could be a modern manager who does not expand knowledge on a daily basis. However, the flood of information makes it important to evaluate the quality of information on which to support one's decisions as to what data to use. One could say that finding 2000 bibliographic sources is as unhelpful as not finding any. We argue that scientometrics should also be a part of the innovatics' toolbox since it has the potential of improving business.

Recently, all academic institutions in Poland obtained access to the most important bibliographic database, namely Web of Science which contains not only data on scientific publications but also data which enable evaluation of their academic quality. Scientometrics teaches us how to sift important scientific contributions, i.e. these that are highly cited, from those that are of marginal value and receive no citations [41]. This is a very effective, and free from "political" influences, way of assessing if a given publication is worthy of attention and if its author represents high academic standards. This approach may be successfully used by non-specialists – for example, by managers working in industry.

Imagine a situtation in which a manager of a firm should decide who to hire as a consultant in a highly technical matter, for example related to the production scheduling, supply chain management or non-financial manufacturing performance etc. How to know who can provide sufficient quality of advice to justify a high fee for a day's work. The advice from such an expert may have a substantial impact on the firm's success in the near or distant future. Very often, helpless manager relies on the only criterion that is easily availabe to him or her, i.e. the current academic or administrative rank of the potential candidates. It is more impressive, but not necessarily better justfied, to hire a director of a research institute instead of a young researcher from the same institute [42]. Scientometrics can provide helpful yardsticks with which to measure academic or professional quality of the candidates: the fundamental measure comes from Web of Science and is based on citation analysis of the candidate's publications. Citation analysis can also help us understand trends in the intellectual development of entire disciplines, as shown by a recent study of the field of operations management [43].

6. Innovatics' toolbox: quantitative methods

6.1. Standards of quantitative description

Quantitative methods should probably be considered the most important tool in the modern manager's toolbox, assisting in quantitative assessment of the state of knowledge, quantitative analysis of experimental or survey data and in building criteria for selecting among the scenarios. All steps are necessary to reach optimum business decisions. However, we feel that there is a substantial disparity, if not a yawning gap, between the level of quantitative sophistication found on the pages of various journals in the field (for example, Management and Production Engineering Review) and the actual skills of managers, even graduates of MBA programs.

Even the most user-friendly, "clickable", software packages will not solve the problem of the managerial "innumeracy", since sensible usage of computer programs requires proper "gut level" understanding of quantitative concepts [44]. Fortunately, computer-intensive methods, such as bootstrap, help in acquiring proper intuitions about even quite sophisticated quantitative concepts [45]. Also, specialized computational methods (e.g. artificial neural networks) allow conducting analyses that reach far beyond simple intutions, but are essential for solving such problems as production scheduling, when limited resources must be allocated to tasks over time and optimum sequence of operations determined [46]. Efficiency of supply chains, which are extremely complicated dynamical systems (affected by many factors, e.g. customer demand, selection of equipment, machinery, buildings and transportation fleet) cannot be assured by managerial intuition alone [47]. In manufacturing industries, equipment maintenance administration may be assisted by software based on genetic algorithms to reduce maintenance costs and production loss caused by equipment breakdown [48].

Theoreticians and practitioners in the field of production management usually do not have to be convinced about the importance of quantitative methods. On the other hand, Albert Einstein tried to bring the quantitative thinkers down to Earth by saying that "not everything that can be counted counts, and not everything that counts can be counted". For example, human intelligence is, undoubtedly, something important (or "counts"), but we do not know how to measure it, even if we think that we can count all the components that contribute to the overall intelligence. All attempts at computing an index of intelligence are weighted by a substantial load of tacit assumptions as to the ways in which the contributing variables should be combined and how their weights should be entered in a formula.

Similarly, building indeces of innovativeness or competitiveness of countries or firms must be based on making decisions about e.g. what variables they will be based on, what measurement scales they are measured on and what weights they will be assigned. For example, Global Competitiveness Report 2008-9, published by the World Economic Forum, was based on 12 main criteria, each assessing very complex issues, such as: the quality of infrastructure, macroeconomic stability, quality of higher education, innovativeness etc. Each of the criteria comprised several partial variables – there were altogether 131 such contributing variables. Only robust quantitative analyses can deal with such complexity of data.

Sometimes very important issues, e.g. whether lean manufacturing improves firm performance (using objective, externally audited, measures of firm performance) and leads to profitability, are left undecided because of the methodological difficulties with computing reliable measures of non-financial manufacturing performance [49]. Also, estimating the throughput of production systems is extremely challenging, especially if we look for analytical solutions in the case of complex systems (assembly/disassembly, parallel lines, split and merge, closed-loop), with added realistic features (e.g. when machines are unreliable) [50]. Even sophisticated statistical methods cannot help if there are basic conceptual difficulties with defining variables, e.g. skill endowment in the company. Is a simple ratio between productive (blue-collar) and non-productive (white-collar) workers sufficient to measure skill level [51]?

Without quantitative methods one cannot conduct a reliable analysis of the quality of scientific research on which a given branch of industry is based, and one cannot analyze or predict the trends of its development [2]. The same, quantitative standards of methodological rigor apply in the evaluation of national, regional, industry-wide trends in market needs, macroeconomic climate, R&D and patent activity [52; 53].

6.2. Managers as statisticians

The quantitative nature of an approach which is based on statistical tests of hypothesis will guarantee (in the statistical sense, of course) high quality of decisions made by managers or entrepreneurs. One could protest: what does hypothesis-testing have to do with managerial practice? In fact, however, the multitude of dimensions of reality in which the firm functions, requires an ability for integrating a great amount of information: rejecting the least important and assigning more weight to more important information. Each decision is an end-point of an often unconscious process of quantitative assessment of phenomena. Gigerenzer [54] called humans "intuitive statisticians", since all our decisions are actually based on statistical reasoning.

For example, data obtained in industrial experiments may be of much better quality if we apply the statistical methodology of multifactorial experiment planning. Consequently, one complex experiment may yield much more information (per unit cost) than several simple (or one could say – simplistic) unifactorial experiments. Then, thanks to a battery of statistical tools known as the Response Surface Methodology [55; 56], we can explore the landscape of responses and localize that particular combination of conditions which generate the most desirable outcome.

Several single-factor experiments cannot reveal exactly that aspect which often hides the most valuable information, namely: interaction between factors. Interaction is an extraordinary (and often: unexpected) result obtained at some particular factor level (e.g. temperature) but only at some particular level of another factor (e.g. humidity or pressure). Similarly, combinatorial chemistry or superconductivity are two fields which are based on the search for interactive, unique mixtures of chemical compounds. Their combined properties result in the overall effect which is either the desired chemical activity or physical characteristics (low electrical resistance). Also, one of the methods of creative solution-generation, morphological analysis, is based on exactly the same principle: searching for unique combinations of features.

Another example of increased analytical power obtained by managers thanks to statistics are methods of meta-analysis. It is a modern way of combining research results from many studies (which may differ in research designs, sample sizes etc.). Since it takes into account also effect size, it represents a significant step beyond reviewing research results using only the traditional "for or against" criterion.

Standards are rising every year; in the past – even applying the Student's t test was a sign of great methodological sophistication; today, however, much more refined statistical methods are expected. Since they are a prerequisite for an optimal or a closer-to-optimal managerial decision-making, those entrepreneurs or managers who can use them will achieve competitive or corporate advantage.

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