Inventive activity: features of the first stages

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Abstract. The Paper presents theoretical and empirical findings about inventive activity. Major invention process models are considered, their comparative analysis is carried out, and their advantages and limitations are revealed. The least studied first stages of inventive activity were theoretically identified and became the main objective of this study. To specify the content of the first stages of the inventive process, an empirical study was carried out through the methods of peer review, written and oral surveys, content analysis and modelling. The study involved 15 experts, namely inventors with a significant number of patents. Based on the survey of experts and the analysis of other authors' investigations, the content of the first stages of inventive activity was specified and conclusions were drawn about their variability as well as the possibilities to apply them in developing inventive abilities and enhancing technical innovation processes.

1 Introduction

Inventive activity is a creative process aimed at translating the obtained scientific and specifically professional and industry knowledge into intellectual property objects. The latter are currently granted legal protection, for example a patent (invention, utility model, industrial design) or a software state registration certificate. However, the principal idea behind an inventive activity is that an engineering invention (engineering creativity) allows to solve complex and non-trivial engineering problems resulting in "new means of production" [1] and innovations expanding and enriching the field of engineering.

Since the inventive activity of engineers is a key factor for an innovative industrial development, innovative skill development should become mandatory for engineering students, primarily for those in master's degree programmes. On the other hand, this task is rather challenging as an inventive activity is creative with its nature and mechanisms that are less clear than those of any other activity. Accordingly, it is much more difficult to form and develop it in comparison with a specific professional activity.

Engineering invention is at the highest level of scientific and technical creativity, especially for students still mastering the profession. In addition, inventive ability is increasingly necessary for productive engineering activities. In high-tech industries engineers are required to apply their competencies and experience to solve known (sufficiently algorithm-based) problems as well as to set tasks and solve them constructively for creating technical innovations by means of engineering inventions. Inventive abilities of engineers are the major tool for solving modern problems of accelerated technological modernization

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and creating breakthrough technologies. Therefore, it is essential to find how inventive abilities could be best and effectively shaped in the process of university training of engineers.

To study the first stages of inventive activity that initiate the creative process and largely determine its effectiveness, the authors applied the methods of expert evaluation, written survey, oral conversation, decomposition, content analysis, modelling, and structural and logical analysis. The experts were employees of the engineering departments of Ural Federal University with experience in inventive activity and having from 18 to 175 patents and copyright certificates.

2 Research analysis of inventive activity structure

Researchers in various fields of knowledge from philosophy, psychology and professional pedagogy to engineering, heuristics and jurisprudence have been focusing on inventive activity for decades. Experience and results of its research can now be attributed to multidisciplinary and interdisciplinary areas. Understanding the basic elements, processes, stages, and mechanisms of inventive activity is of great importance in order to purposefully shape and develop it in young people at the early stages of training engineers with creative abilities.

Having reviewed rich data, the Russian engineering theorist Engelmeyer P.K. proposed one of the first models of inventive activity in the form of a “three-act” creative process scheme [2]. According to Engelmeyer P.K. inventive activity should be considered in three acts. The first act (psychological stage) is an act of intuition and desire; the origin of the idea. The second act (logical stage) is the act of knowledge and reasoning; the development of a plan or scheme. The third act (constructive stage) is the act of skill; constructive implementation of the invention [3].

Three stages in inventive activity were also distinguished by two more famous Russian scientists of the first third of the twentieth century. In 1920 Bloch A. M. identified the following stages: 1) the emergence of an idea (hypothesis, design); 2) the emergence of an idea in fantasy; 3) verification and development of the idea [according to 4]. Levinson-Lessing F. Yu. defined three stages of the invention process with somewhat different content: 1) the accumulation of facts through observation and experimentation; 2) the emergence of an idea in fantasy; 3) verification and development of the idea [5].

At the next stages of studying this problem, dozens of inventive activity models were developed. Meanwhile, there was a tendency to increase the number of stages of the inventive process. Consider the most interesting of them to enhance our insight into the content of an inventor’s creative activity.

The American psychologist Rossman J. used the results of a questionary-based survey of several dozen inventors to develop a seven-stage creative process model [6]. At about the same time the Soviet psychologist Yakobson P.M. identified seven stages of invention process having analyzed the replies of outstanding inventors (A.N. Tupolev, F.I. Kazantsev, and others) to a 90-question questionnaire [7] and the above-mentioned Rossman’s model To understand the inventive activity, these approaches are presented in Table 1.

Table 1. Comparison of inventive activity models presented by J. Rossman and P.M. Yakobson.

Stages distinguished by J. Rossman	Stages distinguished by P.M. Yakobson
1. Observation of a need or difficulty	1. Intellectual and creative readiness
2. Analysis of the need	2. Observation of a need

Continuation of Table 1.

Stages distinguished by J. Rossman	Stages distinguished by P.M. Yakobson
3. A survey of all available information	3. The birth of the new idea – problem statement
4. A formulation of all objective solutions	4. Finding a solution
5. A critical analysis of these solutions for their advantages and disadvantages	5. Getting the principle of invention
6. The birth of the new idea – the invention	6. Converting the principle into a scheme

Noteworthy is that the authors have a common understanding of the first stages of inventive activity. They both believed that the first stages are associated with the development and analysis of a need to create an invention. Though the inner content of these stages is not disclosed. Despite some similarities, the differences in these models are much greater. First, they differently evaluate the most important actions in the inventive process. J. Rossman highlights the importance of processing data, analyzing solutions available, and creating a new idea, while P.M. Yakobson focuses on the general logic of the invention process and the disclosure of the main idea in the form of principles and solution schemes. J. Rossman emphasizes the actions that form a new idea and P.M. Yakobson does the actions that implement it.

A number of later inventive activity models tend to enlarge stages, generalize them and conceptually analyze and describe (Table 2). British researchers M. Thring and E. Laithwaite [8], along with J. Dixon [9] focus on the preparation for creative activity and its psychological analysis. The Russian researcher P.M. Mazurkin, on the contrary, considers the entire invention process as a rational analytical activity with recommendations and algorithms provided for each stage [10]. Unlike the researchers cited above (Table 1), all three authors do not recognize the importance of motives and needs in creating an invention and do not consider their formation as a separate stage of the inventive process. The British specialist D. Beers, another world-renowned specialist on the development of creative projects, does not include motives and needs in his invention formula as well [11]. Failure to consider previous experience (J. Rossman and P.M. Yakobson) proves the first stages of inventive activity to be insufficiently studied.

Researchers from Russia are more likely to single out motivational stages in inventive activity. The inventor A.P. Sobolev identifies the stage “the desire to create something new” “in the most complex creative process of invention and rationalization” [12] but does not reveal its content. V.V. Popov in his work on scientific and technical creativity [13] analyzed the barriers an inventor faces when creating a new solution. He considers the concept of a barrier to creativity as a psychological barrier or motive reducing the effectiveness of creative activity at different stages. According to his concept, the motivation of inventive activity plays an important role, but on the other hand, the only function in it is to create obstacles and difficulties. For example, a value-oriented barrier creates difficulties in motivating and determining the concept of creative activity [14]. These authors in general recognize the importance of motivational mechanisms in the inventive process, and yet neither analyze their content nor single out specific types of motives. The importance of a more detailed study of the first stages of inventive activity is highlighted by these findings.

Table 2. Comparison of inventive activity models presented by M. Thring, E. Laithwaite, J. Dixon and P.M. Mazurkin.

M. Thring and E. Laithwaite	J. Dixon	P.M. Mazurkin
1. Selection of an invention object	1. Preparation: knowledge accumulation, skill development, problem definition	1. Preliminary stage: scope of future research results, research purposes, concept study
2. A formulation of the basic rules of "the game": primary and secondary objectives, restrictions	2. Concentration of efforts: hard work aimed at obtaining a solution	2. Survey stage: theoretical studies; development of techniques; field and laboratory measurements
3. Moment of inspiration – creative act: accumulate emotional charge able to suppress its inner objections and prejudice and to open the way to a new idea	3. Period of pause: mental rest when an inventor is distracted from the task at hand	3. Mathematical stage: measurement and test analysis; statistical modelling of connection between factors; identification of stable patterns
4. "Crystallization of an idea" by the principle of "method of successive approximations"	4. Inspiration: getting a new idea or modifying an already known one that is a desired solution	4. Analytical stage (factor analysis) – analysis of patterns
	5. Completion: generalization, evaluation	5. Information and implementation stage: developing a new way and/or device; writing an invention application

3 Empirical study of the first stages of inventive activity

In order to clarify and specify the inventive process in modern conditions where both invention objects and computational and analytical means of technical creativity have significantly changed, as well as to clarify the content of the first stages, an empirical study was conducted through written and oral interviews. Respondents were experienced inventors with 18 to 175 patents for inventions and utility models, as well as copyright certificates.

The study was aimed at examining the initial reasons, actions, and phenomena with which the inventive process begins and unfolds. As can be seen from Fig. 1, almost all the reasons for the emergence of an invention idea (the name "invention" here means a new technical solution with patentability features that can be patented as an invention or utility model) indicated by the experts are motivational reflecting specific needs in the inventive activity.

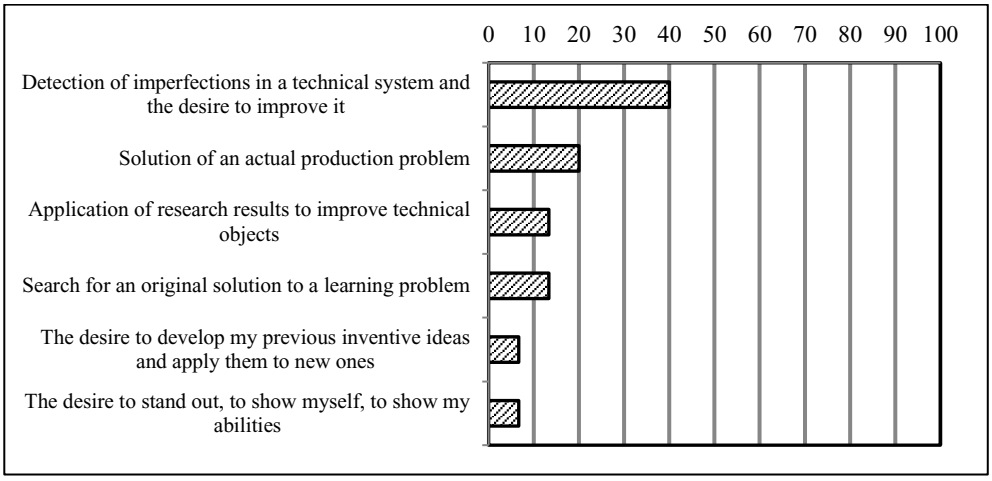

Fig. 1. Reasons for the appearance of the concept of invention and their application frequency.

Responses given by two thirds of the experts to the first two and the fifth questions reflect *the motive of achieving success* expressed in the desire to test their abilities, to achieve better results for themselves, and the *professional motive* aimed at getting satisfaction from the process, content of work and quality of its results. The third and fourth answers characterize *the self-realization motiv*e and *the cognitive motive* expressed in the creative activity of developing and discovering new things. The sixth answer reflects more *the motive of self-affirmation* – the desire to prove themselves in a group or society, and *the motive of social recognition* expressed in the desire to stand out among others, to be known to many and significant to others.

Survey findings shows that inventive activity can be based on quite different motives, but few of them are related to the need for creativity. This fact lets us draw a preliminary conclusion that both specialists focused exclusively on creativity and those with other internal and external motives become inventors. Hence, a much wider range of technically competent people can be more actively involved in the inventive process.

At present, creative activity is mainly engaged by those who have found a specific interest in it either on their own or through interaction with experienced inventors. These enthusiasts are obviously insufficient for Russia to equal the number of patents obtained in other countries (China, Japan, and the United States) being leaders in technological development. Given enterprises and engineering and scientific organizations create enabling conditions for satisfying the motives of success, social recognition, professional growth, and self-affirmation in inventive activity, the number of people involved in the inventive process will significantly increase.

The study of types and forms of activity that form the idea of developing an invention reveals that most experienced inventors act according to the usual pattern, that is they look for and analyze similar solutions either in their own or in related fields of activity (Fig. 2). At the same time this figure shows that research activity – searching for new knowledge and research results as well as conducting their own scientific research – is less typical but not rare in this situation. According to the survey results, the method of creating database for problem comprehension along with the method of versatile analysis and modelling of an object related to the inventive problem are less frequently used to form the idea of an invention.

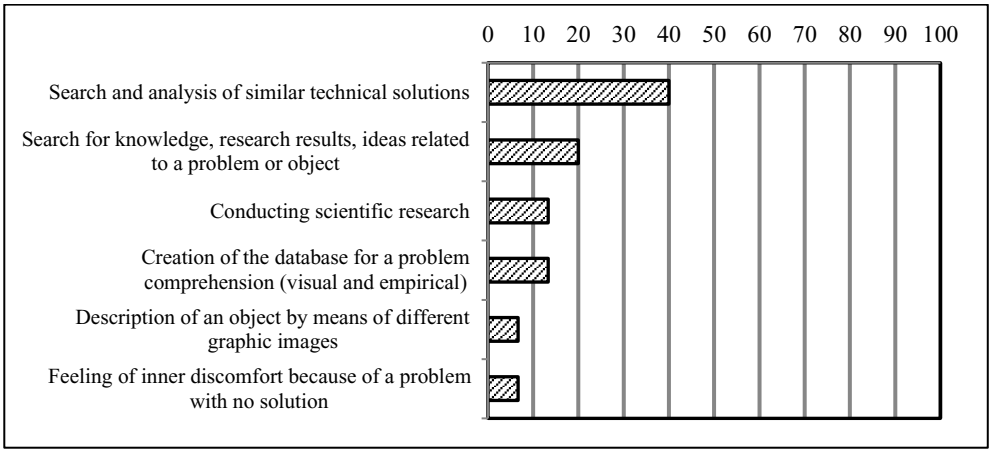

Fig. 2. Actions forming the idea to develop an invention and their application frequency.

One expert indicated not actions but the state that precedes and stimulates the formation of an inventive idea (Fig. 2). "Feeling of inner discomfort due to a problem that has no solution" is a state that is likely to reflect subconscious activity. According to the model developed by M. Thring and E. Laithwaite this activity is called the accumulation of an emotional charge that can suppress one's inner objections and prejudices and open way to a new idea [8]. Based on the survey results, such mechanisms for a new idea formation are characteristic of few inventors.

The survey results obtained (Fig. 2) indicate (i) the dominance of the established stereotypical modes of action to form an inventive idea, (ii) the existence of new opportunities and the expansion of the range of effective actions to achieve this goal, and (iii) the possibility of developing a procedure for complex actions. Moreover, different approaches including common, rare and new ones used in solving completely different problems can be integrated in this procedure.

Significant methodological experience in developing universal chains of actions to obtain patentable ideas is accumulated in Russia and a few other countries. There exist opportunities for expanding the range of ways to form new ideas and build new creative complexes for their generation. Specifically, methodological developments within the Theory of Inventive Problem Solving (TRIZ) by G.S. Altshuller are recognized worldwide [14, 15]. Various heuristic techniques are used as an alternative and less rigorous approach to obtaining original ideas [3, 13].

Most of the experienced inventors served as experts in this study were formed as inventors in the spontaneous process of development and self-development of their abilities. Studying their experience enables one to identify those processes and actions that can be used in the organized training of future creators of technical innovations thus allowing them to quickly master the secrets of this complex activity and become successful inventors.

4 Conclusion

Based on the analysis of study findings, a conclusion can be made about the important role of motivational mechanisms in inventive activity and their significant diversity found in different authors of inventions. The experiences of fifteen inventors revealed at least six different motives that "trigger" the process of invention creation. Referring to the basic regulatory functions of motives in human activity, it is easy to assume a difference in emphasis, techniques, and meanings, and, accordingly, in the courses of further invention

process. The latter are important to understand in order to improve the quality of invention activity training, to increase the efficiency of its organization in enterprises, and, consequently, to increase the total number of those involved in it.

The study of conscious actions and tactics aimed at forming an inventive idea showed the presence of established stereotypes that most inventors use for this purpose, and at the same time the possibility to diversify the operational composition of creative activity that can enhance the creativity of one of the first stages of invention creation.

Understanding the processes and mechanisms of the first stages of inventive activity provides additional opportunities for purposeful improvement of inventive activity and creation of organizational conditions that are believed to increase the efficiency of inventive activity applied in knowledge-based business operations, or even to update and create educational programmes for training young inventors in various educational organizations. All these tasks meet the need to ensure an accelerated growth in the number of new technical solutions protected by patents that will directly influence the technological sovereignty of Russia.

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