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CREATIVE PROBLEM SOLVING IN SOFTWARE ENGINEERING ORGANIZATION

Summary: The aim of the article is to present the neglected issue of creativity in organizations in Poland in the context of the knowledge workers' environment. For instance, software development processes demonstrated the possibilities of expanding functional flow with creative problem solving (CPS) operations. Also, there were presented empirical works and creative techniques used, which contributed to finding new and unique problem solutions. The text can be a theoretical background for undertaking empirical research in the field of creativity in the organization and contribute to filling knowledge gaps in Polish literature on creativity in knowledge-based organizations.

Keywords: creativity, software engineering, management, projects.

JEL Classification: O31, O32.

Introduction

In the organizational environment, one can observe all activities aimed for increasing the efficiency of functioning at many levels of structural units and communities of various groups of employees. This activity is dedicated to the management team, which equipped with various tools for initiating changes or responding to problems, also has the competences to stimulate innovation and creativity. How could it be implemented? The answer might be found in the practices described in the literature. In course of activities stimulating creativity, the amount of information in the form of business and scientific analyzes is narrow. And if a limitation is introduced to the types of business projects, including software engineering, it may turn out that the number of publications on creativity in IT projects in Poland is reaching a vacuum. The few studies currently con-

ducted in the field of organizational creativity as a context of managerial activities prove that activating the creative potential of employees undertaken by managers is ambiguous. Some researches show that higher management does not feel responsible for bearing the burden of creating behaviors activities among its subordinates [Moczydłowska, 2018, p. 124]. In addition, managers are not interested in seeking effective solutions to increase the innovative creation of products, processes or services offered by their organizations. In a strongly competitive environment, human capital may be the decisive factor, and creativity of employees as part of it.

1. Creativity and innovation

What is the difference between creativity and innovation? There are many definitions and descriptions of these concepts in the literature, while finding the answer can cause many problems. One concern can be certain. The mutual relations of these two concepts figure the thesis that without creativity there is no practice of innovation. Therefore, creativity can become an area in itself, as recognition to it, there will be possible to generate new and unique ideas, albeit innovation itself, without creativity, would not create unique products or services. In such a premise, we can assume that creativity is a fuel for innovation, without which the latter cannot exist. However, in order take full advantage of the driving force of creativity, a social unit should be equipped with personality traits conducive to creative thinking, intellectual potential, which does not have to be high above average and experience in the field of creative exploration. The connection point for both concepts, as it is with the rest of the space for every element of the socially created world, is human. Each innovative model consists of elements for which one should have an individual attitude and personally contracted roles. Where creativity meets innovation, there is always an "activator" and "creator". Sometimes, both are one person competences. "Activator" initiates the entire innovation process, whereas the "creator" comes up with ideas that are unconventional and original. As a result, they become innovations [Trias de Bes, Kotler, 2013, p. 20]. The relationship between creativity, as creative activities in the organization and the effectiveness of the functioning of processes, in various organized social structures is directly proportional. Creative attitude favors solving organizational problems, and creative attitudes intensify introduction of unique ideas and shape an organizational culture focused on developing skills and teamwork [Korkosz-Gębska, 2014, p. 960].

2. Technical society

Software engineers are among knowledge workers [Jemielniak, 2008]. It is a group of explorers, distributors, knowledge administrators and finally creators of new knowledge. Hence the assumption, that programmers are creative employees. On the basis of existing research, about half of employees in this category believe that creating software uses creation for new solutions [Zięba, 2012, p. 91]. Creativity refers to production of state-of-the-art or new ideas that are useful to organizations and project teams. It entails changes and behaviors that are inconsistent to accepted norms and values in organizational culture. Creativity research in organizations is aimed at learning the causes of the creative activity of individuals and teams in organizations [Carmeli, Gelbard, Reiter-Palmon, 2013, p. 97]. It was observed that the main obstacles to creative problem solving and related to the employee's personality concept are pessimism and self--centeredness, whereas what is characteristic of creative unit, there is expansive and transgressive behavior [Gurmińska, 2015, p. 209]. Correspondingly, there are studies on the use of psychological indicators in software engineering. They describe the relationship between affective states, creativity and analytical problem solving skills of software developers. They support the claim that satisfied programmers are better at solving problems in terms of analytical skills than their less fortunate counterparts [Graziotin, Wang, Abrahamsson, 2014, p. 1].

It has been assumed that supportive leaders can ease employee creativity by creating psychological conditions, cultivating high-quality relational exchange and generating positive energy, as well as providing constructive feedback. Other studies support this concept, suggesting that transformational leadership is the key to increasing employee creativity. Finally, the researchers drew attention to the importance of building and nurturing a climate for creativity [Carmeli, Gelbard, Reiter-Palmon, 2013, p. 99]. For technical creativity, occasionally, there is no universal approach that would allow solve technical problem in creative way. Therefore, it is important to analyze the problem itself before taking action using creative techniques [Wasilewska, Knosala, 2015, p. 33].

Software engineering, one of the main concepts in this work, as a series of technical activities is based on knowledge that takes into account human and social factors at all stages: creating requirements, designing, building, testing, implementation, operation and project management. There are no members of development projects who have all the knowledge necessary to perform all activities. This is the basis needs for communication, collaboration and knowledge sharing, between the client and the development team [Crawford et al., 2012b, p. 20].

3. Creativity in software engineering and software development

Software engineering is the field of knowledge that organizes different sub--processes of software development in a topic manner. It is a systematic way of application typical engineering activities to software development. It refers to such a methodical procedure, used in the context of a generally accepted set of goals for analysis, design, implementation, testing and operation on software [Leach, 2016, p. 10]. Requirements engineering is part of that software engineering process. Latter came into common use during the NATO conference in 1968 [Edwards, 2003, p. 6; Leach, 2016, p. 1] and since then in software engineering has been included such processes as: implementation, training, creating documentation, testing and programming, and alongside them: feasibility conditions, system analysis and system design. It is a complex problem solving system, because the context of requirements changes when building the system and when the competitive environment changes [Aurum, 2003, p. 71]. However, the rank and meaningful of the use of creativity methods and techniques in this process has been given in recent years in review papers [Lemos et al., 2012].

4. Models and approaches

Currently, the most widespread methodologies for running software development projects are Waterfall [Royce, 1987] and Agile methods [Ambler, 2002]. Waterfall strictly recognizes "requirements engineering" process, therefore will more convenience to take into account during analysis.

Both of them can utilize the Scrum compliance framework [Takeuchi, Nonaka, 1986, p. 138; McKenna, 2016, p. 31], in which the team of stakeholders works in time intervals, close relation with each other. The phase of product discovery, new functionalities are the term used to jointly describe early actions to create a real, desirable and feasible vision of the product. These initial actions represent a different set of challenges, and our understanding of their exact impact on the product remains unclear. Therefore, researchers are increasingly inclined to use different combinations of methods, for instance: the agile method with the Waterfall method and with Scrum elements [Werder, Zobel, Maedche, 2016, p. 47]. In addition, it is pointed out that creativity processes have been recognized not only in these methods, but also for such as Extreme Programming [Crawford et al., 2012b, p. 20].

5. Requirements engineering

Depending on the objectives, software engineering possesses several stages of software production. Among them, there is always a requirements stage. In the general definition of the process, the requirements are defined at the "specification" stage depending on the formula and method adopted. For example, for the Waterfall process requirements are repeatedly found in "system analysis" and for the Agile process at the "planning" stage. It has been assumed that requirements engineering is not perceived as a traditional process of creation, but it can be seen as a trend that requires engineering, with emphasis on development, analysis and management [Maiden, Gizikis, Robertson, 2004, p. 1]. Software development is a problem-solving activity, from the beginning of broad concept of planning to the testing phase. Many of these problems can be creatively resolved. Creativity is particularly important in the requirements engineering phase. The obvious case is that the market products must contain innovative features to attract customers. One of the main challenges associated with adoption of creativity techniques is to determine which techniques to use in a specific context. Both the creativity techniques and software development phases have special features. There is a formula that classifies creativity techniques and assigns them to software development phases so that programmers and engineers can choose the most suitable for their purposes. Requirements engineering includes activities in the field of: identifying stakeholders, identifying different points of view, understanding problems, determining scope, and developing, negotiating, documenting and approving requirements [Vieira, Alves, Duboc, 2012, p. 285].

Creating requirements is a creative process in which stakeholders and engineers work together to create ideas for new systems that are ultimately expressed as requirements. It is expected that the importance of the creative system and product design will increase over the next few years. Creativity is essential for more innovative product development, and requirements are a key abstraction that closes the results of creative thinking about the system. In studies on the possibilities of creating a new air traffic service system, creative workshops were conducted at the Air Space Management, which used brainstorming, constrain removal techniques and analogical reasoning [Maiden, Ncube, Robertson, 2007, p. 1], which led to creation of an innovative approach to the problem and implementation innovative project. The research results show that at the stage of setting requirements in the software engineering process, in the majority of scientific publications focus their analysis on the so-called elicitation requirements

[Lemos et al., 2012, p. 5]. It is a practice used in the search and discovery of system requirements from users, customers and stakeholders, with the indication that not all requirements are obtainable from these sources. This is because the client or other user may not be aware of their existence [Pressman, 2005, p. 257]. Therefore, developing requirements is also a place to conduct workshops and use creative techniques [Gause, Weinberg, 1989, p. 109].

6. Creativity techniques in requirements engineering

Requirements engineering as part of discovering new functionalities through the course of the process uses creative techniques, which usually include three groups [Boden, 2004, p. 3]: exploratory, that is generating new ideas by transferring ideas from analogous domains (analogy techniques); transformative, in which people change the space of the solution in such a way that things have found impossible are now possible; combining, where creation of new ideas takes place from the combination and synthesis of existing ideas [Svensson, Taghavianfar, Gren, 2015, p. 107]. In a few empirical studies, detailed information was provided on the techniques that have been used in the above groups. For exploratory techniques, functionality of the "hall of fame" technique was investigated. This creativity technique helps participants to move away from the most obvious and reasonable perspectives, consulting their beliefs and ideas with the best minds of the world, or the most famous in their scientific discipline or profession. There were professions selected for the study, which made best analogy to the problem area.

In the research carried out by R.B. Svensson and M. Taghavianfar and L. Gren [2015, p. 67], the figures of Z. Ibrahimovic, A. Strindberg and I. Bergman were used. Workshop participants took the heroes to force connections and generate new requirements for their projects through consultation with known people. A method of "ideas box" is selected for the group of combining techniques. This technique starts with defining the challenge and objectives and then choosing the parameters of the given goal. Next a list of options is created for each factor, and finally the participant should try different combinations to find new concepts and requirements. The "constrains removal" method was tested for the group of transformation techniques. During the workshops, participants identified and then removed project restrictions, later identified and created new ideas based on these deletions [Svensson, Taghavianfar, Gren, 2015, p. 68].

N. Maiden et al. [2010, p. 62] listed the techniques that were handled in software engineering, according to M.A. Boden [2004] segmentation. In the

exploration group, he placed techniques: KJ-method, Snowballing, brainstorming, sticking dots. For the combination group: selecting multiple random stimuli, and for transformational: assumption surfacing and boundary relaxation. A description of these methods is presented by M. Michalko [2010].

In dominant publications, importance of creativity was explored at all stages of the software development process and mainly concerned requirements engineering. One of the conclusions is that in process of creating new solutions one should keep an appropriate distance to ideas proposed by programmers, because it is supposed that they can be carried far beyond the client's interest to understand what needs to be invented. However, requirement analysts are ideally suited to creating innovations. They understand the business problem, have updated knowledge about technology, and understand whether inventions are appropriate to the study. In short, requirements analysts are people whose skills and positions allow, even encourage, creativity. Then most engineering tasks in terms of requirements are exploration, acquisition and discovery of requirements and knowledge about the field of the problem. Specialists in software requirements clearly focus on combination and transformation creativity [Crawford et al., 2012b, p. 21].

Statistical analyzes carried out in IT project environments reveal that the requirements generated from the extended process of creating "epic" events, i.e. from the Agile procedure presented in Figure 1, are rated as more novel and original in comparison to "epics" in the requirements register [product backlog] created in a standard manner [Hollis, Maiden, 2013, p. 82].

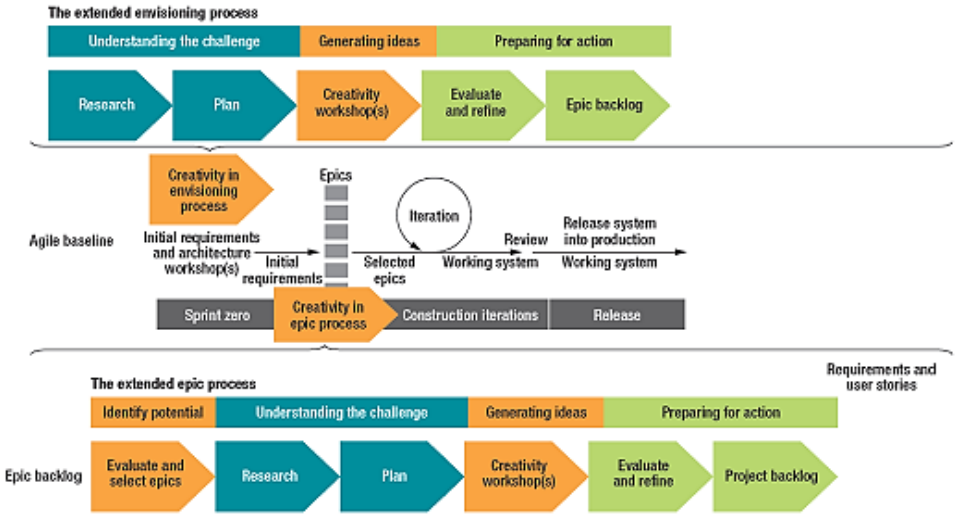

Fig. 1. An extended (creativity) Agile process

Source: Hollis, Maiden, [2013, p. 79].

Stages of the CPS process were divided into three phases [Treffinger, Isaksen, Dorval, 2003]: understanding the challenge, generating ideas, and preparing for action, with an optional preliminary phase, identifying potential for discover challenges that can take advantage of creativity techniques. The key stages in the three main phases include building capabilities, collecting data, shaping the problem, generating ideas, developing solutions and building acceptance. In the framework described Figure 1 some CPS stages and Agile processes are equivalent. Data mining can be mapped using data analysis techniques, such as people who act as "proxies" to investigate a domain when interested parties are not directly available. Similarly, cropping the problem can be mapped to the development of "epic" and user history in the sprint and outside it. The development of the solution can be modeled during early sprints, and the acceptance of ideas can be mapped to subsequent sprint activities, such as iterative reviews, software functionality and launching the production system [Hollis, Maiden, 2013, p. 79].

7. Creative problem solving (CPS)

The main purpose of converting the processes and adding to them a new model using creative techniques was to create opportunities and spaces in which the problem is explored. The result of combining Scrum and Agile processes with creative techniques and workshops is the creation of a solution, a new process or a unique product. Thus, the creator's intention of this solution was to "inject" into the process of creative techniques that could generate original and useful requirements [Hollis, Maiden, 2013, p. 78]. Based on the Agile methodology and Scrum iterative guidelines, it was proposed to develop the process with CPS techniques and creative workshops. An exemplary scheme of processes is presented in Figure 1. It is put forward within to include the so-called extended envisioning process during the "zero sprint" to discover new and unconventional visions of the system and high-level requirements known as "epics". As mentioned before, the requirements are also subject to evolution in a creative mode, there could be found while discovering "epics" as potential results of solving problems or delivering a new product or service.

As previously indicated, three phases can be distinguished in the process of creative problem solving [Treffinger, Isaksen, Dorval, 2003]. The first one is connected with understanding the challenges and, in particular, defining the research problem. In most cases this stage is neglected, but as Charles Kettering,

the inventor of the car starter has rightly pointed out: "well-formulated problem is half-solved" [Szmidt, 2013, p. 80]. In order to trace possibility of solving a problematic situation, at this stage of the process it is recommended to carry out a three-stage analysis of the problem: objective-finding, facts-finding and problem-finding in accordance with the guidelines provided by A.B. Van Gundy [1987, p. 75].

In the second phase, tasks related to generating ideas are implemented, in which different techniques are used to stimulate creative thinking, e.g. brainstorming, ideas box, lotus blossom and many others depending on the type of problem [Michalko, 2010, p. 172]. The third phase includes activities related to preparation for operation. Based on the generated ideas, understanding and acceptance of the team for further action is developed to extend selected solutions. Other methods of creative problem solving described in the literature [Van Gundy, 1987; Higgins, 1994; Mich, Anesi, Berry, 2005] refer to this scheme. In most cases, apart from the special role of the analysis itself, its surroundings, recognition, identification and creation of assumptions, authors suggest conducting training sessions of creative thinking. This aproach is to prepare and tame the participants of the workshops to mental tasks, to create new thought patterns, so that during the proper session, everyone is intellectually ready.

8. Problem definition

Primarily described method of "breaking down" the problem into several phases of analysis, i.e. its correct interpretation and understanding sense and goals the solution, was presented by A.F. Osborn [1953]. The purpose of problem definition is to determine the properties of a problem by breaking it down into different parts. The preparation is intended to help understand the problem details by collecting relevant information about it. The Osborn's phase of finding ideas has been used to generate potential ideas and then refine them to make them as realistic as possible. The search for solutions, the third stage, is used to evaluate ideas and select those with the greatest potential for resolution [Van Gundy, 1987, p. 4; Osborn, 1953, p. 252]. It is the most common model of creative problem solving found in the literature, which is also used to create innovative solutions, products and services. The six-step process consists of: 1. Searching for goals (problem); 2. Searching for facts (regarding the problem); 3. Finding the problem (final definition); 4. Finding ideas (to solve the problem); 5. Finding the solution (based on the generated ideas); 6. Search for acceptance, or the

stakeholders consent to choose a solution [Maiden et al., 2010, p. 59]. The scheme of behavior adopted by the authors concerns the use of one creative technique.

E.D. Mumford [ed., 2012, p. 8] emphasizes, similar to A.B. Van Gundy, to problem being analyzed before subjecting it to processes using creative techniques. In the early stages of creative problem solving, it is underlined importance of problem definition first place, then collecting information about the problem. Before the stage of generating ideas, there indicated the need to review various concepts, their mutual relations and combinations, and the choice of the problem determination. At this point, it is valued to observe the proposals for categorizing problems presented by the author, which states that only well--structured problems do not require solutions from the initial phases and can be subjected to "creative processing", while in the class of a poorly defined problem it is necessary to use initial mechanisms to define the proper problem [Mumford, ed., 2012, p. 178]. In a similar convention, problem concept is classified by A.B. Van Gundy, where mentioned well-constructed, poorly structured and partially constructed problem. For the first one, it presents an analogy to the assembly of the bicycle, which is a well-organized problem, because all that has to be done is to follow instructions. Out of these three types of problems, usually poorly constructed problems will be the most difficult to solve. Due to the lack of certainty and the need to design a non-standard solution, there will be needs to devote the most time to dealing with these problems. For this reason, it utilized the most efficient and possibly effective method [Van Gundy, 1987, p. 2].

9. CPS solutions

The original methods of creative problem solving, such as CPS or synectics, have been developed using a set of creative techniques that are widely used in organizations. Literature review reveals 100 different creativity techniques that allow you to find innovative ideas and many of which appeared in many projects regarding software requirements [Maiden et al., 2010, p. 62].

One of the creative problems solving process version includes a proposal that takes into account element of "incubating" ideas. During the activities that generate new ideas, it is necessary to use breaks in the workshops for relaxation related to avoid intellectual overload. In this part, the participants are offered a momentary detachment from considering the problem and dealing with completely different tasks or rest. Once, the distancing achieved (incubation) allows contributors to start their cognitive systems that evoke so-called illumination.

There appear ideas for a solution, which source could be found in the effort put in training session and during the workshops. In discussed process, training session is included in a "pre-preparation" stage. Then, it takes place the part, in which the solutions relevant to the problem are analyzed. "Final preparation" encompasses use of knowledge and analytical skills searching for factors and variables of the problem. In a "generation of options", the mechanisms of associations, combinations and interpretations are activated so that there is the opportunity to think about the developed alternatives at the "incubation" stage. "Choice of options" corresponds to the final evaluation of the chosen solution, which in the last phase of "persuasion" closes the creative process. Finally the results are communicated to all stakeholders [Crawford et al., 2012a, p. 2].

An interesting solution used as a method of creative problem solving is so-called "a guide to creativity patterns" [Vieira, Alves, Duboc, 2012, p. 286]. It was developed to encourage and support the practice creativity techniques in the context of software development. To this end, the following actions are taken: 1. A known structure of design patterns is adopted; 2. Illustrates techniques with software-related scenarios; 3. Language adapts to software engineers; and 4. A model layout with decentralized columns, symbols and distinguished concepts. The authors present the process formula based on the technique: "reverse brainstorming". It helps to solve problems through a combination of ideas and reversed techniques. First, the problem is presented in the opposite direction to the intended solutions. Second, the problem or challenge is clearly defined, such as "how to stop the loss of information from the database". Then, the problem is reversed: "how to cause information loss from the database?" or "how to make the database unavailable?". Based on the reverse problem definition, basic brainstorming is carried out. Once there has been the list of ideas obtained, the replacement occurred the way that each one meets the original requirements – to create solutions to the right problem. In subsequent phases, other exploratory or combination techniques may be used if necessary. The last stages are checking the feasibility, usefulness of ideas and implementation possibilities [Vieira, Alves, Duboc, 2012, p. 286].

Another way to stimulate creative problem solving in the context of software requirements is the proposal of the "six triggers" presented on the basis of C. Burnay, J. Horkoff and N. Maiden [2016]. The following elements and notions were distinguished: "entertainment", in which the solution is expanded with a function that makes it an entertaining or captivating idea; "light" in which the solution is tried to simplify, making its structure lighter and understandable; "adaptability", here, it can be replace many solution with one adaptable product;

"economy" – in this phase, the solution is updated so that it consumes fewer resources; "comprehensiveness" – creation a more integrated and more comprehensive solution; "durability" – consisting in finding a function through which the solution will be permanent. In this way creativity focuses on the elicitation requirements and can be applied to various approaches and methodologies, like Agile or Waterfall [Burnay, Horkoff, Maiden, 2016, p. 8].

10. Other approaches

Creative processes are closely related to the transfer of knowledge and knowledge management in general. The factors that influence success in using creative techniques are knowledge and experience of the individual. Therefore, an effective approach to creating unique ideas depends on the knowledge and experience of people participating in creative processes. In the case of the environment that produces the software, the most popular techniques used in inventing the requirements identified as: "brainstorming", "role models", "storyboarding". These are dedicated to problems that affect all stakeholders in the project [Crawford et al., 2012b, p 2]. Research results indicate that the brainstorming technique produces more ideas, while the "hall of fame" method generates the most creative ideas. In addition, it provides the largest number of requirements for software that have been included in the final output [Svensson, Taghavianfar, Gren, 2015, p. 66].

The legitimacy of using training sessions is conditioned by the cognitive considerations of the human mind. N. Maiden, A. Gizikis and S. Robertson [2004, p. 3] applied creativity techniques included analogical reasoning and generation of random ideas (random idea generation), storyboarding. It was indicated that research in cognitive science revealed that analogical reasoning is difficult to implement without prior learning. In addition, creative thinking requires a period of preparation and incubation, during which participants gain knowledge about the problem domain, trust and the basis of cooperation. Therefore, it is inappropriate to expect that unique ideas are generated from the beginning [Maiden, Gizikis, Robertson, 2004, p. 8].

Exploitation of various creative thinking techniques aimed for generating many ideas of solutions. A problem situation is aimed at supporting the delivery of ready remedial actions at various organizational levels. In addition, this approach can be used to penetrate the real essence of the problem [Kosała, 2013, p. 108]. Once founded, it may be possible to get a solution at an early stage, and creative techniques will not have to be used at all.

Conclusions

In assessing the operational activity of the organization at the level of innovative product, service or process solutions, more and more often indicators describing human capital and creativity are being adopted. Less well-known methods of measuring creativity in an organization include "the method of weighted labor costs of Hermanson" and "Flamholtz reconstruction method" [Lipka, 2012, p. 453]. However, there is no better way to measure creativity capital [Dobija, 2014, p. 23] than the general formula of DCF (discounted cash flow). Thus, the human capital measurement model H(T) is supplemented by the component R – creativity capital, in so doing: H(T) = K + E + D(T) + R, where: K – capital from maintenance costs, E – capital from education, D(T) – capital from experience, R – creativity capital [Renkas, 2017, p. 421]. In this way, an attempt can be made to analyze the effectiveness of managers activating creative processes in the organization. This study has been narrowed down to the field of software engineering in organizations focused on profit in highly competitive environment. Hence supporting employee creativity can and will bring tangible results. A wealth of creative techniques, including creative problem solving (CPS), that are optimally and properly implemented in organizational processes, is a powerful tool that strengthens the employee's competence potential at every level in the organization's structure.

The models of creative problem solving presented in this paper were selected from majority of the most frequently used in software development and development projects. They will be used as a methodological basis during following empirical research among programmers employed in high-tech organizations.

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KREATYWNE ROZWIĄZYWANIE PROBLEMÓW W WYTWARZANIU OPROGRAMOWANIA W ORGANIZACJI

Streszczenie: Celem artykułu jest przedstawienie pomijanego w literaturze zagadnienia kreatywności w organizacjach w Polsce w kontekście otoczenia pracowników wiedzy. Na przykładzie procesów tworzenia oprogramowania zademonstrowano możliwości rozszerzenia przepływu funkcjonalnego o kreatywne rozwiązywanie problemów CPS (*Creative Problem Solving*). Przedstawiono również prace empiryczne oraz wykorzystane w nich techniki kreatywne, które przyczyniły się do znalezienia nowych i unikalnych rozwiązań problemu. Tekst może stanowić teoretyczne zaplecze dla podjęcia badań empirycznych w dziedzinie kreatywności w organizacji oraz przyczynić się do wypełnienia niedoborów wiedzy w polskiej literaturze o kreatywności w organizacji opartej na wiedzy.

Słowa kluczowe: kreatywność, inżynieria oprogramowania, zarządzanie, projekty.