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A Didactic Application of the Theory of Creativity in School Education

Dydaktyczne zastosowanie teorii kreatywności w edukacji szkolnej

SUMMARY

The teaching process depends on various factors. This paper attempts to show that two factors have a significant impact on the acquisition of knowledge, namely the personality of the teacher and the individual perception of the new material by the student. One of the main tasks of teaching and upbringing is the development of individual thinking. Different paths of development of logical thinking in the didactics of natural sciences have been defined, while there are no descriptions of ways for developing the right-hemispheric thinking and the implementation of image-centered teaching. Teaching children creativity allows to perform appropriate pedagogical technologies. The aims of the CARUS method are based on structural and functional transformations and the use of main strategies in creativity (combinatorial activities, analogue search, reconstruction, universal strategies, resultant exchanges) and tactics (interpolation, duplication, reproduction, convergence, deformation/transformation). The psychological characteristics of the CARUS system are education with the use of hindering conditions. The development of creative strategies constitutes an important indicator of the mental formation of the individual.

Keywords: teaching creativity; pedagogical technologies; strategy; thinking; method

The teaching process is known to depend on numerous factors. Two factors appear to have a significant impact on the acquisition of knowledge, namely the personality of the teacher and the individual perception of the new material by the student.

Features of thinking, memory, various individual peculiarities of the course of mental processes, differences in working skills affect the learning outcome. Knowledge of processes of individual information processing, perception and understanding of

material as well as the way of thinking are necessary for the efficient organization of educational activity, choice or creation of the appropriate pedagogical technology.

The student, in a teacher–student interaction, is stated to be a thinking active personality who responds to the teacher’s requirements and can be an ally of the teacher or his/her opponent (conscious or unconscious). Moreover, neither the student nor the teacher can choose one another. The most important thing that a teacher can provide his/her student with is to assist in understanding and developing his/her personality, confirm the importance and significance of his/her work, its results, promote creativity, help in choosing new ways of personal development.

A creative personality, who is capable of generating and using innovative (new ideas, approaches, solutions) strategies, is best oriented in difficult and ever-changing conditions of the life, resolves the most problematic conflicts and works more productively. According to the theory of creativity of Andrzej Góralski (2002, p. 62), creativity is a generic trait of man and humanity. On the other hand, it is a kind of craft or skill, or human action, in which there are traditions, masters, corporations, professional secrets and rules that can and must be taught. Thus, the process of studying at school is not only possible but also necessary to be connected with creativity, introducing the basic principles of the theory of creativity into the practice of teaching.

One of the main tasks of education and upbringing is the development of thinking. The creative process is the creation of a meaningful context. The correlation of theoretical and practical, logical and figurative components of thinking is of great importance for the formation of creative personality. Right-hemisphere spatial thinking is simulative. It provides the ambiguity of the context that is the essence of creativity. Left-hemisphere thinking, being discrete and analytical, forms a model of the world that can be embedded in words or other symbols. The main function of the left hemisphere is the discrete transformation of information. It is responsible for discursive conceptual thinking, predicting future events, hypothesizing. In the process of perception, the right hemisphere stores the image of the perceived information, the left one is responsible for creating corresponding images of the word. The left hemisphere transforms accumulated images into images – concepts. By operating them, the person creates images – ideas that form the core of the strategy of the creative thinking process.

The right hemisphere is a carrier of human creativity, capable of perceiving multiple relationships and organizing a multifaceted context. It requires less psycho-physiological effort from creative people and occurs at a lower level of brain activity than during the formation of a mono context. On the other hand, both types of thinking require equally high brain activity from individuals with low levels of creativity. But even under these circumstances, the solution of creative tasks is not effective.

Individuals need more effort to overcome the setting formed in the learning process for the rigid subordination and unambiguousness of links between objects and phenomena (Szwaj 2016, p. 71). Both brain hemispheres are involved in linguistic and spatial tasks. On the other hand, they differ in the scope of capabilities within a given

function, and according to another hypothesis, differences in the functioning of the cerebral hemispheres are the result of their various information processing strategies (Senderecka 2007, p. 150).

The teacher should be able to recognize non-verbal signals of his/her students, be aware of his/her thinking style as well as students' thinking style, differentiate interactions with them. For right-brain students it is necessary to rely on the social significance of one or another type of activity, because they have a high need for self-realization. Motives that encourage learning are related to the process of a person's self-formation, a desire to grasp the essence of human relationships, realize their place in the world. Thus, they are characterized by a high assessment and praise orientation.

It is necessary to rely on cognitive motives in order to form motivation for educational activity in left-hemispheric students. They like the process of mastering the knowledge and the high need for constant mental activity is inherent for them. The social motive is the opportunity to continue education. Right-brain students are in a state of constant stress if the teacher requires them to work with out-of-context material.

But they succeed in lessons where the same tasks are presented in context (algebraic constructions are used to calculate household expenses; familiarization with new words occurs in the process of reading, narration, equation of chemical balance is maintained through laboratory experiments). Left-hemispheric students rarely struggle during lessons, because a lot of processes happen out of context. They may not see the whole due to the concentration on separate parts. In classes dominated by right-brain students, regardless of the teacher's characteristics, any activity becomes synthetic. The left-brain teacher appreciates the children of his/her own type better, the right-brain and equal-brain teachers in most cases give a positive assessment to the students of their type. In this case, left-hemispheric children happen to be in a risk group.

Although imaginative thinking prevailed in childhood, "(...) the whole modern education system is aimed at the development of formal-logical thinking, mastering ways of constructing an unambiguous context" (Szwaj 2016, p. 72). This can be considered a systematic mistake, since the more effort is put into the learning process to dominate formal-logical thinking, the more effort will then be required to overcome its limitations. The teacher's activity should be focused on the development of the right hemisphere in order to form creative personalities. The result also depends on the particular type of ability.

The ease of transition from the abstract to the concrete, and *vice versa*, indicates a good integration of both components of the right and left hemispheres. This, in turn, testifies the flexibility of thinking, the ability to move away from stereotypical thinking and overcome the psychological barrier of the standard approach to phenomena (Szwaj 2016, p. 72). Modern learning technologies are required to develop different types of students' thinking. The didactics of the natural sciences has identified different ways

of developing logical thinking, but lacks to describe ways to develop right-thinking, the introduction of image-based learning. To paraphrase Góralski's (1998a; 2002) statements, it is necessary to teach students the ability to marvel at the world – this is the task of the modern school.

The need to inoculate, along with the skills of logical thinking, also the skills of heuristic thinking upon students is a central theme of the Hungarian mathematician George Pólya. He paid a particular attention to the creative solution of mathematical problems, believing that "(...) the art of solving problems gives us the opportunity to form in students a certain mindset and inoculate appropriate concepts, which are an important element of the general culture" (Pólya 1976, p. 315). Didactically, this is done in a sophisticated logical system of algorithmic instructions (advice – recommendations or questions), with the help of which the teacher can appropriately direct the student's efforts in the desired direction and facilitate his or her independent search for solutions (Pólya 1961, p. 202). Creativity is to manifest itself in combination, transformation and ways of applying search schemes.

Creativity is "a force that adds dynamism to the daily lives of people, business, art, science, public activity and almost every sphere of our existence, and it can be considered as a common good that must be valued, supported and developed" (Szmids 2019, p. 10).

The most well-known programs and methods of creative development include: CoRT by Edward de Bono (1976); Khatena Training Method (Joseph 2009); Pardue Creative Thinking Program (Feldhusen, Speedie, Treffinger 1971); Future Problem Solving Program International (FPSP), which was developed in 1974 by a creativity pioneer Dr. Ellis Paul Torrance; Future Problem Solving (FPS); Theory of Inventive Problem Solving by Genrich S. Altshuller (1973); CARUS method (Molyako 2008); brainstorming method of Alex Osborn (1993); SCAMPER method; Fritz Zwicky's Morphological Method of Analysis and Construction (Zwicky 1969); Edward Nęcka's creative solution to problems (Nęcka 2008), Góralski's functional analysis (1998), Pedagogy of Creativity and Creativity Training of Krzysztof Szmids (2008; 2012), Yakov Ponomarev's central link of the psychological mechanism of creativity (Ponomarev 1976).

The creativity mechanism functioning undergoes several phases (according to Ponomarev), namely: 1) the logical analysis of the problem – the use of available knowledge, the existence of the need for it; 2) intuitive solving – meeting the need for something new; 3) verbalization of intuitive decision – acquisition of new knowledge; 4) formalization of new knowledge – logical thinking development (Ponomarev 1976, p. 328).

Solving problems is stated to be possible by means of creative thinking. Problems in general are subjective, and their solving requires intellectual activity (for example, additional knowledge). Ponomarev identified the central link of the psychological mechanism of creativity. He claimed it to be characterized by the unity of logic (action with character models) and intuition (action with originals).

If the structure of creative potential according to Valentin Molyako (2008, p. 54) is to be followed, and includes informational and instrumental components, then the analysis of the content of the concepts of “creative abilities”, “creativity”, “creative potential” shows that they differ from each other by the presence of the component in the last structure of the information that is necessary for solving problems. The information component of creative potential embraces specific knowledge and skills. The instrumental component includes techniques, methods and strategies for solving creative problems, thinking (divergent, logical analytical and synthetic), memory, performance, problem perception, individual components of the motivational and emotional – volitional spheres of personality (openness to research, endurance, readiness to take a risk, non-conformism, perseverance, will).

With the help of appropriate pedagogical technologies it is possible to teach and develop creativity at schools. According to Molyako’s (2018) research, creative work in the intellectual sphere is the most difficult one, and learning in the conditions of creative work to some extent guarantees further successful activity in less difficult conditions, as well as a constant focus on rationalization of the work, improvement of its quality and efficiency. Molyako’s method CARUS (2006) is designed for structural and functional transformations as well as the use of the main strategies in technical creation (combinatorial activities, analogue search, reconstruction, universal strategies, resultant exchanges) and tactics (interpolation, duplication, reproduction, convergence, deformation) and integration of the basic part, autonomy, sequential subordination, shifting, differentiation) of constructive activity.

Molyako has identified five main technical strategies for creativity, namely (Molyako 2006, p. 24):

- 1) searching for analogues (analogy strategy),
- 2) combinatorial operations (combining strategy),
- 3) reconstructive activities (reconstruction strategy),
- 4) universal strategy,
- 5) random substitution strategy.

The strategy of searching for analogues is associated with the use of a known structure or its part and the function in the process of creating a new device. A newly created item must contain something innovative or be used in new conditions. Creating a new construction can be associated with such analogues that exist in nature. Of course, artificially created constructions can be very different from their live analogues.

The strategy of combinatorial operations means using various mechanisms together and their functions to build a new construction. Combinatorics is associated with different permutations, decreasing and increasing in size, changing parts in an already existing structure.

The reconstruction strategy is related to the restructuring, moreover of antagonistic nature. This is a remodeling, or more precisely, designing on the contrary.

For example, the direction of rotation or type of transmission may be changed, the rectangular part may be replaced with a round one, etc. It can be concluded that reconstruction is the most creative approach associated with the search for a truly new one, different from the one previously used. Of course, the scope of creativity will be different: only one detail can be changed in the device, but you can rebuild the entire structure.

Universal strategy is associated with a relatively equal use of analogy, combination and to some extent reconstruction. This is a variant when it is difficult to offer an advantage to one of them.

The strategy of random substitutions – there are cases where it is generally problematic to determine the nature of an entity's actions when there is no dominant tendency, and the search is done as if blindly, without a plan, or at least neither the subject itself nor the external observer can establish such logical connections. Each strategy can be implemented in the form of a synthesis or analysis.

The psychological characteristic of the CARUS system is stated to be education with the use of impeding conditions. Therefore, special methods are used:

The time constraint method takes into account the significant impact of the time factor on mental activity. Without a time limit, the entity finds several options for solving the task, thoroughly rethinking its activities, as well as the quality and structure of the objects sought. In the limited time the subject either limits the use of what he or she knows best (most often it is the use of a template variant), or decisions to a certain extent are deformed. Through the type of these deformations one can determine the general tendencies of human mental activity. People react differently to time constraints. In some cases, the limitations increase the activity and get even higher results or changes in behavior, decrease the results and fail to achieve the result. Limited time causes inhibiting, shock, that induces doubt, panic and quick refusal to complete tasks.

The method of sudden prohibition (MSP) consists of prohibiting the use of certain mechanisms in some of its structures. This method is also quite effective, because it destroys stereotypes, eliminates the possibility of using well-known types of devices, nodes and parts. So certain styles of activity, related to specific techniques and mechanisms are quite naturally trained by constructions. The use of MSP will contribute to their ruin. Adaptation to the application of this method is related to the reappearance of these trends in activities that are habitual and usual. The use of MSP promotes the development of the ability to change their activities depending on the specific circumstances.

A quick sketching method is necessary to diagnose specific features of mental activity. It is possible to suggest a continuous “drawing” of the reasoning process – presentation of all constructions. Thanks to this technique, it is possible to more accurately determine the transformation of images, the concepts and visual images of the given structure. It accustoms to greater control of the activities, regulation through images of creation process.

The method of new variants consists of the necessity of different problem solving, searching for new variants of problem solving, which always leads to the increase in brain activity, creative search. This method can be scanned at any stage, not only after finding a solution (in a sketch version). Then this method can be transformed into a ban method.

The method of lack of information is used in the case of the need for a special activation of operations at the first stages of problem solving. In this case, problems are reported with a significant lack of initial data necessary to run the solution. Thus, there may be one or more functional and structural characteristics of the initial data (direction of motion, speed of rotation). An important modification of this technique is the use of various forms of presentation of the initial state. Particularly, one can offer tasks, initial conditions of which are presented graphically or only in text form. The method is particularly effective in studying the peculiarities of understanding while discovering available knowledge.

The method of informative supersaturation is based on the conscious inclusion of unnecessary information to the initial conditions of the task. A variation of this method is a tip administered orally and contains unnecessary data that diverts attention from useful information. The teacher decides how to apply the method: to propose the choice of the relevant information or avoid mentioning that there is an excessive amount of information.

The absurd method consists of a specially proposed task that cannot be solved. A typical option for absurd tasks is to build an eternal engine. You can also promote problems that are relatively absurd (for example, suggest a device design that can be used for a different purpose than required at the beginning). It helps to fight with thinking templates and to reach another level of creative problem solving.

The method of situational drama, depending on the specific pedagogical idea and process of solving the problem, introduces some changes in the process of solving. These changes are designed to impede the activity and can be very diverse – from the teacher's question ("question-plus") to different requirements not provided to ordinary procedures. The sudden ban method is a variation of this method. Each of these methods can be combined with others and have various modifications.

The creative activity of people, their specific actions that characterize the specificity of thinking, are only partly dependent on the conditions and largely reflect the personal preferences, strategies of the subject and the style of his/her creative activity. Formation of creative design thinking, creative strategies and tactics through CARUS creativity training is based on the laws of creative activity of professional workers (engineers, teachers, doctors, etc.), takes into account the specifics of creative activity, includes the basic techniques of existing methods of stimulating creative activity and can be used at every stage of the creative process as an effective means of stimulating creative thinking.

Studies have shown that the formation of creative strategies becomes an important indicator of mental upbringing of the individual (Molyako 2018). That is why Molyako

offers the following basic forms of creativity training: systematic resolving of various creative tasks through a special creative training, maximum aesthetization of all forms of life, starting with inculcating students with skills of accuracy and ending with assimilation of the world's cultural heritage, participation in the work of creative circles, societies, etc.

Heuristic methods are being intensively used in a learning process nowadays. They are a set of performing activities using a system of thoughts and practical action, appropriately planned and organized. The purpose of heuristics is to develop effective methods for solving problems. General heuristic principles are detailed in methods and techniques for solving problems. Heuristic problem-solving techniques tend to stimulate intuitive thinking, generate new ideas, find effective problem-solving strategies. The unlimited use of the heuristic is determined to be its advantage while the expected result cannot be obtained due to the negative impact of various factors that have not been taken into account and is considered to be the disadvantage.

Learning methods are suggested to be used to develop the creativity of students in the process of teaching physics, the source of which are the methods of pedagogy of creativity and methodology of creative activity. The development of students' creativity can be embodied in two models of teaching physics: a) a model of learning, which distinguishes special lessons of physics (creativity as a subject of study); b) a model of learning that is implemented through the enrichment of an existing syllabus in physics (creativity in content and teaching methods). The second model does not require additional time and financial costs and is ensured by the application of a strategy concerning the enrichment of physics teaching with creativity trainings. That is, creativity is stated to be a method of learning.

Creativity trainings in physics teaching are structural elements of both the traditional lesson and other forms of learning process organization and are aimed at providing a creative learning environment that has an impact on students' thinking and readiness for creative activity:

(...) creativity training in the process of teaching physics is a system of didactic group lessons, which are structural components of educational process in physics and are conducted with the purpose of developing the creative potential and creativity of students, forming their motivation and life experience, creative approaches to solving problems, ensuring balance between the cognitive and affective development of the student's personality. (Shvay 2011a, p. 199)

The tasks are designed in accordance with the curricula for creativity trainings during the lessons of physics (Shvay 2011a; 2011b). Such tasks are introduced.

Exercise "Creating New Concepts". Exercise for the development of creative imagination. Students are asked to come up with the name of a non-existent object (phenomenon) and verbally describe its appearance and usage (the object can be depicted).

Exercise "Creating Remote Associations". Creating star-type associations is to surround the original concept with a certain number of associations that relate

only to the reaction to that concept but not to the previous associations (window – transparent medium, window – world, window – light beam, window – refraction of light; connected vessels – pressure gauges, connected vessels – liquid pumps, connected vessels – hydraulic machine). The creation of a chain of associations is a gradual departure from the original concept through the creation of the following links of the associative chain: a) window – sun – spring – the end of the academic year – summer holidays – new academic year; b) lens – eye – to see – to live – to create; c) temperature – thermal balance – laws of energy conservation in mechanical and thermal processes – heat engines – efficiency; d) sand – footprints in the sand – footprints in the snow – trajectory – uneven movement – speed – car – internal combustion engine – environmental problems.

Exercise “Observe the Diversity of the World” – the need to perform exercises of this type is caused, on the one hand, by the necessity to break the stereotypes of perception of learning situations that are formed when solving most standard tasks, and on the other hand, by the need to shape students’ own outlook. The purpose of the exercise is to form the ability to perceive reality outside the box. This can be done with the help of various tasks – questions:

1. Where does the sugar disappear if it is added into water?
2. What is smell and how it spreads?
3. Why are both chalk and pencil written off?
4. Imagine we are standing on the shore of a lake and looking at the sun. The fish from the water are also looking at the sun. There is no wind and the surface of the lake is smooth. We see the sun at an angle of 30° . At what angle do the fish see the sun – larger or smaller?
5. How do you understand the phrase “I feel warmth”?

Exercise “What Happens If...”. The exercise is one of the ways to change the stereotype of thinking, form a sense of responsibility for somebody’s decisions, and to seek the distant consequences of some predetermined state of affairs. For example, what happens: if alternative time units are used to apply them by different services; if gas (air) does not occupy the entire volume of the vessel (room) in which it is contained; if any objects that surround us do not reflect light or only mirror reflection is observed; if only black and white colors exist; if the molecules stop moving; if all bodies at room temperature are liquid; if all fuel and energy resources are depleted.

CONCLUSIONS

The same operations are equally important for both the intelligence functioning and creativity, thus, creativity trainings are claimed to provide comprehensive development of personality. Therefore, exercises that are used in creativity trainings ensure the development of memory, attention, emotions, imagination, intelligence, metacog-

dition, etc. During the training process, the emphasis should be placed on the level of individual creative components development and abilities of students, it is vital to make the right choice regarding the need for developing individual characteristics.

The model of teaching physics for the development of students' creativity in the process of teaching physics is necessary for the formation of strategies and creative approaches to solving problems, the development of motivational, emotional and volitional spheres of personality, interpersonal abilities, the formation of motivation for creative activity, the development of cognitive abilities.

Pedagogy is interested in all aspects of creativity, but the greatest attention is paid to the creation of a learning environment that influences the development of creative personality, and factors that affect the content, intensity, flow and results of students' creative activity in learning activities. Modern system of education should be focused not only on the development of formal-logical thinking, but also on the visual-figurative one, which is connected with the use of analogy, metaphor and recombination.

Pedagogical methods of creativity, which stimulate the generation of new ideas as well as finding effective problem-solving strategies, facilitate the development of students' creativity. The general heuristic principles are detailed in the methods of solving problems. In order to develop students' creativity in physics teaching, attention should be paid not so much to the results of creativity in the form of a creative product, but to the development of intrinsic motivation, divergent and convergent, logical and intuitive thinking, creative and special abilities, design of behavioral patterns (models) of creative personality according to the demands of the environment and the modification of living conditions that are inherent in an innovative person capable of self-development and self-improvement. Creative work in terms of intelligence is the most difficult one. Training in the conditions of creative work to a certain extent guarantees further successful activity in less complex conditions, as well as a constant focus on rationalizing work, improving its quality and efficiency.

The strategy for the development of science and education in modern conditions implies the creation of alternative planning centers and hierarchical systematization of priority research; creation of specialized and regional sub-centers for solving particular problems on specific sciences, staff training, conducting special (including psychological) research on revealing the creative potential of a person, upbringing, psychological rehabilitation, optimal use of the achievements of science, technology, culture in both professional and everyday life.

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STRESZCZENIE

Proces nauczania zależy od wielu czynników, z których dwa istotnie wpływają na proces przyswojenia wiedzy, mianowicie osobowość nauczyciela oraz indywidualne percypowanie nowego materiału przez ucznia. Jednym z naczelných zadań nauczania i wychowania jest rozwój myślenia jednostki. W dydaktyce nauk przyrodniczych określono różne drogi rozwoju myślenia logicznego, brakuje natomiast opisów sposobów rozwoju myślenia prawopółkulnego i realizacji nauczania opartego na obrazach. Nauczanie dzieci twórczości umożliwia wykorzystanie stosownych technologii pedagogicznych. Metoda KARUS ma na celu transformacje strukturalne i funkcjonalne oraz zastosowanie w twórczości głównych strategii (takich jak czynności kombinatoryczne, poszukiwanie analogów, rekonstrukcja, strategie uniwersalne, wypadkowe wymiany) i taktyki (jak np. interpolacja, dublowanie, rozmnażanie, konwergencja, deformacja/transformacja). Charakterystyką psychologiczną systemu KARUS jest kształcenie z wykorzystaniem warunków utrudniających. Kształtowanie twórczych strategii staje się ważnym wskaźnikiem wychowania umysłowego jednostki.

Słowa kluczowe: nauczanie twórczości; technologie pedagogiczne; strategia; myślenie; metoda