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Theory of problem solving

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Abstract

The article reacts on the works of the leading theorists in the fields of psychology focusing on the theory of problem solving. It contains an analysis of already published knowledge, compares it and evaluates it critically in order to create a basis that is corresponding to the current state of cognition. In its introductory part, it pursues a term problem and its definition. Furthermore, it pursues the problematic situations and circumstances that accompany the particular problem and appear during its solving. The main part of this article is an analysis of the problem solving process itself. It specifies related terms in detail, e.g. the ability to perceive the problem, the perceptibility of the problem, the willingness to solve the problem, the awareness of existence of the problem or strategies of problem solving. Published knowledge is applicable not only in fields of psychology, but also in fields of pedagogy, or education.

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1. Problem and its definition

The human beings are in their lives every day confronted with the situations that are for them contradictory, containing obstructions that have to be overcome in order to achieve the aim, or the human beings experience various difficulties. To cope with these situations, it is desirable to apply the thought processes enabling generating of knowledge necessary for a successful solving or removing of the above-mentioned obstructions. Those situations, raising the inevitably thought processes, are, according to A. M. Matyushkin (1973, p. 20), in psychology called as

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the *problem situations* and the relevant tasks as the *problem tasks*.

The definition of the term *problem* is presented differently, therefore it is desirable to analyse it in detail and define it. Theoretically, a *problem* is understood as a difficulty of theoretical or practical nature that causes an inquiring attitude of a subject and leads him/her to the enrichment of his/her knowledge (Cz. Kupisiewicz, p. 16). This term is in the fields of education similarly understood by a Polish scientist, W. Okoń (p. 79), who defines a didactic problem as a practical or theoretical difficulty that a pupil has to solve independently by his own active research. Usually, the base of this difficulty is a systematic and deliberately organized situation, in which the pupil aspires to overcome the difficulties in accordance to the specific needs and by this he/she gains new knowledge and experience. The analysis of this particular situation leads to the formulation of a problem – to the verbal definition of the occurred difficulty.

The term problem defines J. Linhart (1976, p. 385) as:

- a) problem is an interactive relation between a subject and its surroundings, which incorporates the inner conflict that is solved by the subject by searching of transitions from initial condition to the final condition (aim),
- b) the existence of a conflict causes the dynamics of an activity and, furthermore, it establishes a source of motivated activity,
- c) during the solving of a conflict, the subject exceeds something that is directly stated, i.e. he/she exceeds the current situation and stated information and searches for new approaches.

Duncker (1945) states that a problem arises, when a person has a specific aim but he/she does not know how to achieve it. However, this statement is only one of the possible cases since a problematic relation does not have to be primarily based on the aim of the person, but also on the difficulties and inner uncertainty. The individual is aware of the problem that has already arisen and then he/she establishes the aims to remove the difficulties and uncertainty causing the burdensome feeling. The problem is defined by a relation between the subject and objective situation in the environment. A problematic relation has a nature (Linhart, 1976, p. 78) of:

- a) either a conflict between two contradictory tendencies which the subject sees as two incompatible alternatives, or as a difference or conflict between the current situation and the aim; the subject needs to achieve the aim but he/she does not know the means to achieve it – the result is "a perceived inconsistency" of the situation; the problem solving consists of the removal of the conflict and the finding of the desired object.
- b) a disorder in the objective situation or in the structure of an activity and subjective uncertainty that causes activating tension and motivating focus.

Appropriate conditions enable the formation of a *problematic situation*, in which the individual finds him/herself and that surrounds him/her. According to suitable statement of Cz. Kupisiewicz (1964, p. 16), this situation embarrasses the individual which causes a feeling of a difficulty superimposed by curiosity and strives to satisfy him/her. Acquired forms of behaviour of the individual find themselves in a conflict with the given situation, the individual is forced to adapt to those new situations, to create the new ways of behaviour by which a new balance of the forces is developed therefore the conflict is overcome (comparison to Linhart, 1982, p. 63). The *problematic situation* cannot be confused with a *problem*; this term will be defined later. By studying of the scientific publications we draw a conclusion that the most suitable definition is made by J. Linhart (1976, p. 385), who defines the *problematic situation* as a totality of conditions that determine the formation and specifics of the problem. It is impossible to be fully identified with another definition made by I. J. Lerner (1986, p. 91). He defines a *problematic situation* as a barrier that subject is clearly or indefinitely aware of and to its overcoming he/she needs a creative search of the new knowledge, new ways and activities. However, the barrier is not the only element of the problematic situation - this role is played by the other factors as well.

Analysing the different problematic situations, we draw a conclusion that they are characterized by diversity and it is possible to divide them in the groups based on the similar signs. Considering the understanding and subsequent problem solving, as the most simple situations occur those where necessary pieces of information are apparent and where no unnecessary data, that would have to be filtered out and analysed by concluding operations, are presented. The problem is clear and, basically, it is only a matter of finding its solution. All substantial circumstances are clearly specified: the current state, the target state and the available operators. These situations can be described as

the *specific problematic situations* and as the examples can be named different types of brain teasers. It is possible to meet this kind of problematic situations very often in the field of school education, to which refer Mayer and Wittrock (2006). They state that educational materials very often prioritize well-defined problems; however, the most of the real life problems are defined wrongly. As found, an ease of preparation of those problematic situations from side of the teacher, high number of students and to that related level of the problematic situations contribute to that. Further problems may cause the relative time consuming which is advantageous mainly because of the length of the standardized teaching unit. The opposite situations that can be called as *uncertain* problematic situations are characteristic by the lack of information which has to be firstly gained. Often it is not obvious which information will be needed for problem solution and the problem is not obvious as well as it has to be firstly identified, prepared and defined and later solved. The objective uncertainty is outside the individual who finds himself in the problematic situation. Funke and Frensch (1995) refer to those problematic situations as “non-transparent”.

The problematic situations are possible to be assessed in terms of statics, or dynamics, which is defined e.g. by the authors Blech and Funke (2010), Klieme (2004), Wirth and Klieme (2004). The changeability of the complex of the conditions, that determine the creation and specifics of the problem in time, is determinable. For the problem solving is more advantageous when the conditions are stable and no changes are happening – in these cases is the problematic situation called *static* problematic situation. An example of static problematic situation can be, again, a brain teaser. On the other hand, for the *dynamic problematic situations* is the change of conditions, that determine creation and specifics of the problem in time, characteristic. The conditions can change because of various influences, whose creation and effect can the individual not affect. The on-going consideration of the influences acting in time and their control is an assumption for successful problem solving process in those situations. The dynamics does not have to be in the context of problem solving understood as negative, it can operate also positively, and e.g. previously unsolvable problem suddenly becomes solvable.

2. Problem solving

As it was already discussed above, the thinking of an individual begins with the awareness of the problematic situation. In this case, the problematic situation has a potential to grow into a problem that deserves a solution. Every problem is bound to the problematic situation, however, not every problematic situation turns into the problem because this reality depends on the individual. A person, who finds him/herself in a problematic situation and is aware of its existence, does not have to “see” the problem until the *ability of the problem awareness* is developed. The individual, who is aware of the problem, is able to specify the difficulty or the source of the conflict which causes the problematic situation, is capable to deal with the problem. Contrary to that, the individual who is not able to be aware of the problem, is albeit experiencing the feeling superimposed by curiosity, however, does not realise what causes the difficulty, which obstacle that causes the conflict has to be removed, and, therefore, he is not able to remove it. A lot of factors affect the problem awareness and those can appear inside the problematic situation, e.g.: the inappropriate verbal utterances that should induce the situation or the lack of knowledge. They can also appear outside the problematic situation, i.a. noise, improper lighting or a visual impairment. Taking this into account, we can mention also so-called *perceptibility of the problem*. The threshold of the perceptibility is different amongst the individuals which is mainly conspicuous when more people find themselves in a problematic situations of the same parameters. The exterior conditions of the individual are the same, the conditions directly connected to the individual are different.

If the individual is perceives the problem, *the willingness to deal with the problem* is very essential. This is a state when the individual approaches the evaluation of the circumstances of the problem and character of the problematic situation. He/she evaluates the particular circumstances and he/she attaches a particular importance to them. One of the opinions is that he/she is not willing to deal with the problem in the current situation or to proceed to its solution. This is very important in the educational field because the problems that are given to the pupils should be the ones that the pupils accept willingly and if not, the pupils should be motivated. The reluctance to deal with the problem is going to be obvious mainly in the situations that allow an escape because the feeling of difficulties is not pleasant for every individual.

If the individual is willing to deal with the problem, it does not mean that he/she is going to be willing to solve it. If he/she e.g. does not have the initial data for seeking the ways of overcoming the obstacles and there are no

obvious possibilities to gain the data, then the situation is not accepted by him/her, therefore it will not be reflected in his/her thinking. In this case there is no will connected to the effort to solve the problem going to appear. The *willingness to solve the problem*, similarly as the willingness to deal with the problem, cannot be assumed automatically, therefore it is desirable to induce it with the help of the appropriate resources and ways, and to motivate the individual. R. E. Mayer states that the willingness is affected by motivational and emotional factors such as the interest, the conviction (self-confidence) and the conception of own abilities (1998). In the motivation of the individual can appear interests, habits, ideals or external stimuli, and others, depending on the nature of the problem. The willingness to solve the problem negatively affect three factors that cannot be neglected. M. Nakonecny (1998, p. 458) states that for the individual's willingness to solve the problem and deal with it is essential the probability that he/she achieves his aim. The value of the aim, which should be achieved by solving or the subject's expectations of possible consequences, play an important role as well.

Only two ways of being excited by motives to solve the problem are meaningful in the educational field. First case is to create a situation that excites the pupil, energises him/her, and i.e. induces a state in which the pupil experiences the impulse or forcing to the interest about the problem and its solution. The teacher has to lead the pupil to the experience of wanting to be active. The interest about the problem solving has to be aroused, which enables to satisfy the need resulting from the unfamiliarity, we can speak about so-called cognitive need. M. Nakonecny (Zaklady psychologie, 1998) states that this state is characterised by a particular tension and motive (compulsion), and for that is important to understand the problem and to perceive the obstacle that prevents the achievement of the aim. A problem always contains a conflict or a difficulty, which has to be overcome during the solution process. However, the obstacle has to be conspicuous to the individual so that the conflict or a difficulty are feelable. The mentioned state can be characterised as a disequilibrium and the individual is motivated to balance it which leads to his/her satisfaction. The need is satisfied by solving the problem and gaining the needed knowledge.

The second way is the application of external stimuli that cause inner motives and that are resources of satisfying the individual's inner needs. Instead of desire to solve the problem and satisfaction of the needs regarding its solution the individual him/herself orients to the effective solution of the problem. The purpose stays in this case outside the problem itself because the problem plays only a vicarious role. The pupil solves the problem in order to achieve the aim and the problem solving becomes only a resource. This is in terms of educational results not as beneficial as when the interest in the problem itself appears. It is typical for the school environment to apply the stimuli that are not natural, e.g. the pupil does not encounter grades in normal life.

The problem solving can be according to R. E. Mayer (1990) defined as a summary of the cognitive processes focused on the change of the given state to the final state where the solution procedure is not obvious. The given characteristics is among the experts of problem solving usually accepted (Klieme 2004; Mayer and Wittrock, 2006; Reef et al., 2006). The problem solving and its cause is defined in the work of Funke (2010) who stated that the person's initial knowledge of the problem are the conditions (the given state). The operations are permissible activities that can be performed in order to achieve the required final state (result) with the help of available instruments. On the way to the aim are standing obstacles that have to be overcome (e.g. the lack of knowledge or the directly obvious strategies). The process of overcoming of the obstacles can include not only cognitive but also motivational and emotional aspects.

The solution of the didactic problem begins with *the awareness of the existence of the problematic situation* followed by understanding of its essence. During the problem solving the human being faces many obstacles and meets different possible solutions among which he/she has to choose. His/her personality itself is a very complicated system of characteristics and roles - their interaction is often contradictory. Fight between the motives is conditioned by that, it is characteristic for the active behaviour: attitude and emotionally substantiated wishes of the subject very often collide with the surrounding world (compar. Linhart, 1982, p. 63). The problem solving is a personal and aimed process. That means that the activities done by an individual during the problem solving process are led to his/her personal aim (Mayer and Wittrock, 2006).

An individual has to identify the problem first and then seek for possible solutions (Mayer and Wittrock, 2006). There are typical phases used for the problem solving that are being discussed by different authors, e.g. J. Linhart(1976, p.78) suggests that the subject experiences three phases:

- the discovery of the problematic situation,
- the phase of the solution process, where the subject meets the properties of the situation and seeks for the resources that can change the situation (object) with respect to the required aim and

- the phase of verification of the discovered property or method and its use in other problems of the same order.

It is possible to agree with above-mentioned information, however, the situation is more complex and needs further analysis that emphasises the individual and his/her thinking process and behaviour. The presumptions can be found in research PISA 2012 (*Conceptual framework of the problem solving PISA 2012*) within which the activities of an individual were indicated and evaluated. Those activities are: research and understanding, representation and formulation, planning and performing, observation and evaluation. Not only those ways but also others will be characterised later on.

In literature, it is possible to encounter the efforts of problem solving ways to order the individual phases. In accordance with the authors Lesh and Zawojewski (2007), it cannot be presumed that those activities are performed in an individual order the problem solving, nor that all possible ways are applied. During structuring, representation and solving of the authentic problems that arise from the real life situations is the final problem solving reached in a way that overcomes boundaries of a linear consecution step by step. The before-mentioned authors say that current knowledge of the human cognitive system functioning actually indicates that it can process different pieces of information simultaneously.

The individual, that find him/herself in the problematic situation and is aware of its existence, has to firstly *get to know with the elements, circumstances and influences that create the situation and are a part of it*. The result of this conduct should be the creation of a mental representation of all internal and external entities that are a part of the problem or create it directly. The individual explores the situation with this aim and during this time he/she observes and affects it with an aim to learn it and understand it. It is needed to understand the given pieces of information as well as those that are being gained in the interaction with the problematic situation and the understanding of the particular elements of the problem. The representation of the elements, its bonds, acting effect and registering of the new knowledge, is typical in order to reach the better understanding. Thinking of the individual can then orientate on the insight of the problem, the memory is therefore available for other needs. That enables the creation of the coherent mental representation of the problematic situation in whole, i.e. situation model or the problem model (*Conceptual framework of problem solving PISA 2012*).

The elements, connections and influences in their nature can be formed dynamic, variable in time and space which is negative for their cognition and understanding. However, if they have been already recognised and understood, their changes can be positive in accordance to the problem solving. The changes can then induce appropriate circumstances and conditions.

The problematic situation includes circumstances and conditions that cause difficulty, conflict, unrest, feeling of uncertainty, limitation, or a concern over the disorder. Those can be of material and non-material nature and can require operations with physical objects, things or thought operations. The individual has to perform an analysis of the problematic situation and *prepare a cause of the conflict or difficulty* which causes a problematic state that tempts him to solve, remove or overcome it. The cause has to be distinguished from other entities to ensure a relation to the relating objects and to determine the character of links. The conflict and the difficulty are always palpable, internal and experienced by subject. On the other hand, the causing reason can be palpable and also impalpable.

It remains an open question if the problem solving consists of reshaping the external circumstances and conditions, or the internal ones. J. Linhart (1976) states that the problem solving process consists of reshaping the object and its reconstruction in order to overcome the given problem and to find an objectively needed alternative of solution and negotiation. Considering the characteristics, the complexity of human psychology and the science development, the cognition of a particular situation as a problematic one can be removed by appropriate ways and resources in order to remove the conflict and the experience of difficulties. Therefore it cannot be unambiguously presumed that the problem solving is related only to surrounding world of the individual, however, the essence of most of the problem solving remains unquestionably outside the individual.

If the individual is aware of the cause of the conflict or the difficulty, he/she accesses to the cognition about *what causes it and how can the creation be precluded* – by removal of the obstacles, reordering of the elements system, or ordering the elements into a system. He/she thinks about the kind of resources he/she has, how he/she can use them properly, and what way he/she should choose in relation to its removal. This is a complex of various acts and thought processes that (according to the character of the solved problem) contain manipulation with the objects of material nature; it indicates an interaction, an evaluation of the situation in the new conditions that are distinguished

by changes made by an individual. During the problem solving process the individual has to bear in mind the knowledge of various types and operate with them (Mayer and Wittrock, 2006). During the solving the individual defines hypotheses, gains new pieces of information and finds out gradually which circumstances affect, or don't affect the removal of the cause, the conflict or the difficulty. The structuring of information and their critical evaluating is also being performed. The result of this process is the knowledge that can be transferred and used properly in problem solving of a similar nature. In this context are some problems more or less interactive, e.g. the individual has to affect one or more input variables and evaluate the effect on them. The variables can influence each other which increases the complexity of the problem solving. It is desirable to keep the individual motivated, mainly when there is no longer found the fact that causes the reason of the conflict, or when there is not sure how to remove it. The situation is then demotivating and the individual may refrain from the problem solving.

The problem itself does not show the direction of solution and it does not restrict it (I. J. Lerner, 1986, p. 91-92). It is characteristic for the *problem task* where the parameters and the requirement of the solutions are given. Thus a problem that contains parameters of its solution is a problem task.

For the successful problem solution, it is appropriate to perform the *planning* of the particular steps that lead to its successful resolution. Planning is developed from the circumstances of the problem, contexts and influences that create the problematic situation and, possibly, the stated parameters. The compiled plan does not have to be definite and it is very probable that there will be changes performed that reflect the new knowledge gained during its solving.

Considering the personality of the individual, the used ways for the solution are being settled with higher number of solved problems. It is possible to speak about the *strategy of the problem solving* that can be characterized as a plan of the sequence of steps consisting of application of proper methods and resources that lead to the successful problem solving. The distinctiveness of the circumstances of the problem is being reflected into the strategy. Furthermore, it is being judged by the individual and according to it he/she chooses the form of the individual steps. Those that did not acquitted themselves well are no longer used in the similar problematic situations. The increasing frequency of the solved problems has a formative meaning from this point of view.

Parameters of solution are limiting, regulative and deliberately settled factors: the individual solving the problem is being limited in the possibilities of the solution, the ways are being defined by the parameters, and the forms or resources that can or cannot be used are being defined by them as well. They can also express the resulting quality of the solution. They can be regulated in a way that the problem solving takes place according to the needs of the author of the problem task which is in a certain direction advantageous for the needs of the education; however, they limit the creativity. The given parameters can contribute to the finding of the path of the problem's solution that can unsolvable for the individual without them.

After the fact that causes the reason of the conflict is found as well as the way of how to eliminate it, the individual tries to *remove* it. It is therefore needed to *act* and when it is successful, it removes the cause of the conflict, difficulty and the problem is solved. There are expected skills that the individual has already gained which facilitates the problem solving and mainly in relation to the shortening of the time needed for the solution.

The problem solving process includes also *cognition of progress*. If the solution ought to be successful, the individual has to perceive the aftermaths of his/her own acting in the individual phases of the problem solving, he/she has to *verify* if the action had a positive effect on the problem solving itself, if he/she gets closer to the expected aim or whether he/she gets more distant from it. The unexpected events can intervene in the way of the solving that change the problematic situation and can have an influence on the solving process.

The resolution of the problem can be described as a state characterized as the removal, disappearance or fading of the difficulties, conflict, unrest, feeling of uncertainty, or a concern. The two possible ways of reaching the resolution were already discussed as these are internal and external ways. The solving does not have to be based on the individual who experiences the problem and feels it - another individual or a group of cooperating individuals can contribute to those before-mentioned ways. In extreme cases does not the individual experiencing the difficulty or a conflict have to perform any action and the problem can be solved as a result of the spontaneous change of the acting circumstances or the change caused by another person.

In the literature devoted to the problem solving, it is possible to encounter with a term *competency to solve the problem*. In publication OECD (Problem Solving for Tomorrow's World, 2004) based on researches of the scientific publications is the term defined: *the competency to solve the problem* is an ability of the individual to use the cognitive skills for understanding of the problematic situations and its resolution in case when no obvious way of solution is presented. Its part is also the individual's willingness to deal with those situations so that he/she can grow

his/her own potential as a constructive and thoughtful citizen. It is not important that the competency is defined as ability - we only emphasize this fact, but it is more important to note the following fact: in the framework of PISA from the year 2003 was the competency defined similarly, mainly its first part. As mentioned in publication (Problem Solving for Tomorrow's World, 2004), whereas the definition from 2003 contained only the cognitive dimension and emphasized especially the interdisciplinarity of the evaluation. In 2012 was into the definition added also an emotional component in accordance to the competency definitions of OECD (OECD, 2003). The competency is more than a reproduction of the maintained knowledge - it contains mobilisation of the cognitive and practical skills, creativity and other psychological sources, i.e. attitudes, motivation and values (OECD, 2003).

As mentioned, it is needed to have the knowledge for the solving and successful resolution, it is also possible to speak about the cognition basis. However, that cannot be understood as something closed but as a dynamically developing process of the problem solving because the part of the competency to solve the problems is an ability to actively gain and use the new knowledge in a direct contact with a barrier or a difficulty and action performed on it, or gaining new knowledge from other sources that are also needed for the successful solution of the problem. Even the current, i.e. already gained knowledge before the start of problem solving, can be used in a new way. That enables solution of non-routine, subjectively new tasks.

Time needed for problem solving is a significantly undetermined variable. Time needed for finding and removing is affected by a number of internal and external factors. The external factors are given by their diversity of circumstances and their order, the inner factors are given by inherent and gained dispositions of the individual. It is important to take into account those facts during the educational process where the problem solving is used because the pupils could need a different period of time for the resolution of the problem.

3. Conclusion

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