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Methods for Developing Technological Thinking Skills in the Pupils of Profession-oriented Schools

Zyamil Gazizovich Nigmatov[1] & Iyudmila Nikolaevna Nugumanova[1]

[1] Kazan (Volga region) Federal University, Russian Federation

Correspondence: Zyamil Gazizovich Nigmatov, Kremlevskaya Street, 18, Kazan, 420008, Russian Federation.

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Abstract

The urgency of the problem under investigation is due to the fact that technological thinking skills are today one of the important conditions of polytechnic education and professional orientation of the pupils of different types of schools. Technological thinking contributes to the development of pupils' innovative and inventive abilities, as well as promotes the scientific level of education. The purpose of the current article is to reveal different methods for developing technological thinking skills of the pupils of contemporary profession-oriented schools. These methods are based on the development laws of the features of profession-oriented schools and are focused on the pupils, prone to technological activities. The authors conclude that the considered training methods and techniques stimulate the development of technological thinking skills of the pupils, as well as spark their interest in technological, encourage the broad scientific and cognitive activity that characterizes general labor education of profession-oriented schoolchildren.

Keywords: technological thinking, profession-oriented school, subject-oriented training, technological competencies, development, technological problem

1. Introduction

Active processes of reforms in social and economic spheres of the society have put the theory and practice of technological competency formation at the forefront. In recent decades, "... many companies use the term "competency", which means integrated knowledge, skills, judgment and attributes that are needed to people to effectively perform the work" (Developing a competency framework, n. d.). These processes require comprehensive analysis of established theoretical principles and practical technologies of training and education, whereas such a comprehensive analysis needs the developed technological competency of pupils, especially the upper-form pupils of the profession-oriented school. Moreover, "the development of technological competency in a profession-oriented school should be based on various solutions to challenging profession-oriented technological or physical problems that accompany the learning process of the pupils of profession-oriented school at all stages of mastering the profession" (Nugumanova, 2010).

Since "functional competencies, or as they are called, technological competencies relate to functions, processes… and include the knowledge of, and skill in the exercise of, practices required for successful accomplishment of a specific job or task" (Sturgess, 2012), in the profession-oriented school the solution of intriguing technological problems becomes standard procedure and takes the leading position in the technological thinking development technology. In an age of technological progress, it is important to educate technically literate, deeply thoughtful people-thinkers "who are very practical, technological-oriented and precise. These thinkers rely heavily on common sense, rather than on imagination. Perhaps, one could refer to them as "technological thinkers", as their work is thought out in every detail and deserves all-around support" (Different ways of thinking, 2011).

The importance of training of technological thinkers from their school days lies in the fact that the technological thinking is one of the basic conditions of polytechnic education and occupational guidance. It contributes to the development of innovative and inventive skills, shaping of a stable interest in children not only in technological, but also in science, since technological thinking contributes to improving the scientific level of education.

2. Techniques

Many scientists and practicing teachers emphasize that technological thinking is manifested in the ability of a person to successfully solve technological problems. Therefore, we have logically identified the ability of the pupils to solve integrated technological problems of different complexity levels as the primary technique for development of their technological thinking skills. Under such problems we mean the technological/technological problems, whose solution requires knowledge of all the components that make up a technological mindset. Upon successful solving of technological problems of various complexities, one can judge about person's technological thinking level.

Since a technological thinking refers to a set of intellectual processes and their results, which provide a solution to the problems of vocational activities, the solution of technological problems, from this point of view, is the main method to develop technological thinking. The solution of these problems is based on the following three indicative instructional techniques: first, the definition of objectives, the desire to get an answer to the question posed; second, the need to grasp the essence of the available conditions and initial data and to take them into account; and third, the use of those problem solving methods, which comply with to the given conditions and the initial data. Each of these three factors has a number of features. In the course of work, the pupil should be able to clearly and correctly raise the questions, independently or with the help of teacher, to which he has to answer when solving a technological task. This skill must be specially trained.

Development of technological thinking is possible according to the following methodical algorithm: at the first lesson the teacher demonstrates how to solve typical technological problem, and then proposes to pupils to solve similar tasks independently. The next step is to offer pupils simple technological tasks, though non-standard ones, while illustrating the application of technological thinking, such as search for analogies, using combination and various substitution options, etc. As a rule, pupils show great interest in responding to unusual logical reasoning and are fascinated by the solution of such problems. Methods to resolve any problem, not just the design or process tasks are based on the use of general principles and guidelines, suitable for the given conditions, by adjusting a particular case to the general rule.

General guidelines for pupils to address non-standard tasks can be expressed as follows:

1) When solving such problems, pupils should try to understand the technological sense of all data. They must seek and consider different ways of solving the problem, not dismissing any solution, even seemingly absurd. Since any technical problem can be displayed graphically, the pupils should make various sketches. They should not hesitate to ask the teacher any questions about the task.

2) Once pupils got the "technological" sense of the problem, they must look for analogies and try to find an algorithm for structuring the task and combine. They may search for "up to chance" solution, in other words, any idea that came to their mind.

These recommendations are given to pupils depending on the situation raised in the course of problem solving. Development of technological thinking is possible through the training of each trick.

3. Discussion

Discussion of the "*technological thinking*" concept and its importance for profession-oriented school

The term of "technological thinking" emerged in the psychological and pedagogical literature not so long ago and by many authors is understood intuitively. Most researchers (Gilbukh, Kudryatsev, Maximova, & Yakimanskaya, n. d.) define technological thinking as a process of reflection in the human consciousness of production technology processes and objects, their design and operation principles, as well as the flow of intellectual processes in the sphere of technical images, handling these images using the mental activity techniques not only in a static but also in a dynamic conditions (Yarlakabov, 2011).

Study and analysis of various researches on the problem of the technological thinking development in pupils shows that there is a great diversity in opinions regarding the definition of this concept. Some scholars identify this concept with the concepts of "creative thinking", "reflective thinking", "analytical thinking", "logical thinking" and "critical thinking", i.e. in different sources we can find different interpretation and definition of concerned concept. In our opinion, the concepts of "technological thinking" and "critical thinking" are the most close to each other in terms of their sense. We make this conclusion based on the definition of "critical thinking", given by D. Halpern in "Psychology of critical thinking". According to Halpern, "critical thinking is the use of cognitive skills or strategies that increase the probability of a desirable outcome... Critical thinking also includes an assessment of the thinking process - the course of reasoning that led to our findings, or the factors that were considered when taking the decision" (Halpern, n. d.). The same properties are peculiar to technological thinking.

It turns out that technological thinking is carried out by means of known mental operations (analysis, synthesis, comparison, generalization, etc.), though their course has a special focus. Technological thinking, depending on the tasks facing it, can be theoretical and practical, reproductive and productive, eye-mindedness and visual-active.

Thus, the "technological thinking is a set of intellectual processes and their results, providing the solution to the problems related to technological activities. These can be both design and process tasks" (Test on mechanical comprehension). It should be noted that the problem of development of technological thinking skills in the pupils of profession-oriented schools is studied quite poorly.

Since this article deals with the development of technological thinking skills in the pupils of profession-oriented schools, we found it necessary to discuss also the following questions: "What is the profession-oriented training?", "Which school is considered a profession-oriented?" and "What is the origin and development background of profession-oriented training and school?"

Like many other pedagogical phenomena, subject-oriented training has its background. Many scientists believe that it originated from differential training (in Latin “differentia” means the difference). In relation to the general education school, subject-oriented training is a division of curricula and programs in high school. Referring to history of the national education, we see that the profiling of training in upper school was envisaged as far back as in 1918 at the first All-Russian Congress of Educators, when developing the Regulations on the Unified Labor School. Three areas were emphasized at high school: humanities, natural and mathematical, and technological education. Differentiation of schoolchildren in terms of production training areas and profiles was carried out depending on their expressed aptitudes and interests. Pupils acquired somewhat extended and deeper knowledge in the basic science areas, which were the most significant for chosen specialty.

The prerequisite to a new wave of transition to differentiated (profile) training was, first of all, the initiative of upper-form pupils, and then, the individual schools. Sociological studies show that the most upper-form pupils (70%) prefer to acquire the basics of the main subjects, while to study in-depth only those ones, which are chosen depending on their specialty. In other words, profiling of high school education corresponds to the structure of pupils’ attitudes towards the education and life. Most upper-form pupils believe that the today’s school education does not fully give required and sufficient capabilities for successful admission and training at higher education institution and future professional career building.

Upper level in secondary school seeks to create a "system of specialized training (subject-oriented training) in the upper grades that would focus on the learning individualization and socialization of pupils. This includes consideration of the actual needs of the labor market, detail development of ... flexible subject orientation system and cooperation of high school with institutions of primary, secondary and higher education" (Nigmatov, 2011).

The basic idea of subject orientation even at the higher level of training is that education here should become more differentiated, individualized and therefore more functional and efficient. "Subject-oriented training as a means of differentiation and individualization of learning allows more complete consideration of the interests, aptitudes and abilities of pupils due to changes in the structure, content and organization of the educational process; it allows creating conditions for teaching upper-form pupils in accordance with their intentions with respect of getting professional education" (The concept of subject-oriented training at the senior level of general education, 2002, p. 3). Subject-oriented training enables in-depth study of not just one subject, but several subjects. For example, the natural sciences involve in-depth study of physics, chemistry and biology, while human sciences include Russian language, literature and foreign languages.

Thus, the purpose of *subject-oriented training* is in-depth study of selected subjects. This gives an opportunity for schoolchildren to build their own individual training plan, to provide equal opportunities to study in accordance with their desire and abilities, as well as to prepare pupils for education at higher education institutions.

The main *tasks* of subject-oriented training include developing in pupils skills of independent cognitive activity, preparing them to solve the problems of different complexity, orientation of the pupils in a broad range of problems associated with a particular field of activity, the expansion of opportunities for pupils’ socialization, and much more. Though the main tasks, in our opinion, are the following: 1) to develop in pupil ability to think that would enable him to process the acquired educational information critically and creatively, rather than passively consume it; 2) to give pupils a deep and strong knowledge in vocation-related subjects, i.e. in those subjects, in which they expect to realize their potential after graduating from the school.

4. **The Results**

The results obtained during the use of methods for solving technological problems, which develop technological thinking skills in the pupils of profession-oriented school.

Development of technological thinking is a complex process that usually is pretty slow and depends on person's general intelligence, skills, abilities to technological thinking and other factors. People acquire technological thinking skills as a result of years of practice. Though, it is necessary to start developing these skills at an early age, supporting them at the junior, then secondary and high school. As a result of multiple repetitions the pupils accumulate experience and develop the technological thinking skills. Thanks to the technology lessons at profession-oriented school, where pupils solve a great variety of different kinds of technological and engineering problems, the opportunity for development of their technological thinking skills increases multifold. During these lessons pupils acquire skills, abilities and knowledge exactly in the technology field. Thus, it is necessary to pay serious attention to this aspect.

Conditions and initial data of technological tasks are not always given in the finished form; pupils should find many of them independently and evaluate, whether or not they are sufficient for solving a given task. However, the major difficulties are associated with the problem solving methods. As known, the solutions to any problem are based on the use of general principles in specific conditions, on adjustment of a given particular case to a certain general rule.

Now we consider the most effective, in our opinion, methods of solving technological problems, contributing to the development of technological thinking skills in the pupils, and hence the formation of their technical competencies.

One of these techniques is *development of the strategy to search for analogies*, which includes, first, the explanation of the essence of searching for analogies, their varieties, as well as features of mental activities. Then, the pupil answers the questions: "How one can explain similar solutions?"; "What means searching for analogies?"; "What technical analogies do you know?" Answers to these questions will help to diagnose the theoretical readiness of pupils to solve the technological problems of a certain kind. Satisfactory readiness is supported by showing a solution (collective or individual) to the specific task in a given situation with detailed analysis provided. After the independent solution of technological/engineering problem the pupil is asked to answer the other questions: "What are the other analogies that you revealed?"; "Why did you choose this analogy?"; "What are the difficulties that you experienced when searching for analogies?" Answers to these questions will enable one to give the individual advices on choosing solution strategy to address specialized technological tasks, extensively developing thinking skills and, as a consequence, raising the profession-oriented interest and forming basic vocational competencies.

Further, the algorithm is repeated in increasingly complicated way, where teacher encourages pupil to use more unusual and unexpected analogies. As a result, one proposes a competitive challenge for the most original solution that requires a deep judgment, since judgment "justifies the solution and is based more on facts rather than emotions, analyzes problems skillfully and uses logic to reach a solution" (Competence (human resources), 2014).

In terms of the subject matter, the development of technological thinking, when considering the technique for searching analogies, includes the following: initially, the pupils are explained that this technique is based on the setting of meaningful similarities between the structures, functions, and operating principles of certain technical devices, as well as a technical device related to non-technical problem (insect, animal, et al.). Establishment of similarities between these analogies gives a hint for using appropriate structure, function and operating principles when searching for solutions to the given problem. There are complete or obvious analogies, relevant, hidden or partial analogies, and analogies selected with regard to the certain assembly units. Complete analogy almost indicates coincidence of the structures and functions that makes it possible to transfer the known solution, applicable to the analogue, to the original device.

Relevant analogy is related to the search for possible preferential similarities in terms of structure or functions, while partial analogy reflects the similarity of a single unit or a certain function. One can emphasize the close analogies, conditional or very remote ones. This depends on the class of the technical devices being compared. Close analogy involves comparing the technical objects of the same type, such as for example worm gears for different purposes. Conditional analogy can be found between the gear and the transfer belt, while the remote analogy can be seen between contact and non-contact interactions of different parts of mechanisms.

Such a classification of analogy-based method is usually quite interesting and affordable for pupils of profession-oriented school. During training by analogy-based method one often uses combination and remodeling methods. Pupils' reflections are based on the consideration of possible options of using one or another technical unit, rather than strict logic principles. The main thing is that one must "be able to analyze information quickly and use it in a way that enables obtaining reliable solutions" (What skills and competencies ..., n. d.). At that, it is necessary to liberate thinking, to focus attention on formation of solution strategy, achievement of the end result, logical vision of universality of technological thinking.

Realizing the fact that the "problems, faced by people involved in the technological activities (design, construction, maintenance, repair, and others), have some specific features in comparison to the problems solved in other spheres of activity" (Dushkov, Korolev, & Smirnov, 2005), the technological thinking development arsenal includes the "*random substitutions*" *strategy*. This strategy has even no approximate algorithm, thus its goal is to train one's own thinking not to retreat in the face of deadlock situations. In the simplest version, the implementation of the "random substitutions" strategy lies in the fact that in the case of emerging obstacles during solving the technological problem, a pupil is advised to try any logical idea, which came to his mind, to fix random images, objects, principles, and to try to "fit" them to the problem solution.

The *"Real time constraints" strategy* also significantly develops technological thinking. This strategy is based on the well-known psychological phenomenon, when human mental activity begins to be activated under time pressure. It should be noted that the solution to a technological problem in the free time mode, usually stimulates the pupil to search for several possible solutions, while in the mode of the real time constraint, mental activity is focused on searching of a unique optimal solution. It is important to note the didactic pattern: if the pupil's reference knowledge is actualized, he quickly finds the solution; while if his reference knowledge is not assimilated at the level enabling him to freely apply this knowledge, then the pupil either degrades his results, or comes to a mental "block" and rejects solving the problem. This suggests that the solution of non-standard technological tasks should be preceded by active, challenging, actualizing educational activity, since only positive result provides educational effect and develops technology competencies.

"It is very difficult to know for sure today, what competencies will be eagerly sought in five years. We must not forget that in addition to technological competency, other kinds of skills and knowledge are also important in working life" (Developing a competency framework, n. d.). Therefore, under the conditions of information support, the feature of the technological thinking development in upper-form pupils of the profession-oriented school is a combination of solutions to technological problems in the "teacher-pupil" and "computer program-pupil-teacher" modes.

The *method of sudden prohibitions* can be also attributed to the factors contributing to technological thinking development. The essence of this technique is to restrict the possible solutions to the technical problem (e.g., with respect to kinematic problem, the restriction enters on the use of the certain type of transmission devices). Such approach in solving of technological problem often happens to be original, since it inspires the search for new solution of well-known technical device. Although the "excessive restrictions is another very common barrier that people face when trying to solve problems ...", though "this phenomenon occurs when a person, trying to solve the problem subconsciously, puts boundaries towards solving the problem that in turn makes him strain to be more innovative in his thinking" (Problem solving, 2014).

Using the method of sudden prohibitions in solving technological problems, when training pupils in profession-oriented school, contributes to broadening of the individual style in technological activity. It can be argued that non-standard techniques of mental activities during their assimilation in the training process merge not just into the personal quality, but become the indicator of the professional competency that is especially important for the pupils studying at profession-oriented school.

Another particularly effective technique to solve technological problems, which develops pupils' technological thinking, is the *brainstorming method*. This is the operational method of solving the problem, based on the inspiration of creative activity, in which participants of the discussion are offered to give as many options for solutions to the technology problem, as possible, including the most fantastic ones. Then, the most successful ideas, which can be used in practice, are selected out of the total number of ideas expressed. This method, developed by A. Osborne back in 1953, is based on the assumption that one of the main obstacles in creating of new ideas is the "fear of evaluation"; the pupils, even at a high school, often do not express aloud interesting imaginative ideas for fear of meeting with skeptical attitude towards them on the part of teachers and classmates.

The purpose of the brainstorming is to avoid the evaluation component. The classical brainstorming technique, proposed by Osborn, is based on two main principles: "to postpone the verdict to the proposed idea" and "the quantity produces the quality". In other words, "brainstorming provides free and open environment that encourages everyone to take part. Fanciful ideas are welcome, and all participants to the full extent are encouraged to provide a rich selection of creative solutions" (Brainstorming: generating many radical, creative ideas, n. d.). At that, it is necessary to ensure establishing friendly relations between the brainstorming participants. Smirks, omissions, skeptical smiles, criticisms, etc. are unacceptable. The ideas expressed by one of the participants can be supported by statements of others (Methods of solving new creative challenges, n. d.).

A striking example of the technological thinking development in pupils is the use of the *rapid sketches drawing method*. When pupils draw sketches of any technical object, they develop imaginative vision of the operating principle, the mechanism of electrical or any other circuit. This technique aims at teaching pupils of the technical profession-oriented school to sketch of unfamiliar unit or part quickly and correctly. Prompt sketching can be used also as a test. It broadly describes the features of the pupil's thinking in general and technological thinking, in particular. This technique makes it possible to judge deeply the dynamics of the visual thinking development, to establish the relationship between the comprehension and the image of a certain structure or mechanism. For pupils, this is matter to reflect their activities, to self-control the development pace and assimilation quality of technological competency.

Today, in the age of information and communication technologies, strengthening the motivation of technological thinking can be contributed using *the method of instructional design*, which essentially is a solution of technological problems as well, though deals with complete solution to the problem, related to both "commodity" manufacturing and sale. Though, when employing this technique, one should closely monitor to ensure that the independent work of pupils, as well as the work performed together with the teacher, should be adequate to pupils and at the same time require from them creative concentration of their abilities, appropriate to their age and training level.

It is clear that the above described methods can be applied only by teacher, familiar with these techniques and able to take into account pupil's personal intellectual potential (Kalimullin, 2014). Otherwise, one can achieve the opposite effect, i.e. a complete rejection of this type of activity.

Among the findings of the current study we may note also that the results, obtained on the basis of the systematic analysis of the technological thinking development conditions and the peculiarities of the educational process organization in the profession-oriented educational institution, may be formulated as follows:

- Pedagogical requirements and instructional techniques are enunciated to solve integrated technological tasks, developing technological thinking skills in the pupils at profession-oriented school;

- The algorithm to train technological thinking skills in the upper-form pupils at profession-oriented school, which includes the characteristics of the formed elements and thinking process, has been developed;

- A number of problems, associated with the development of technological thinking of the pupils at educational institutions in general and profession-oriented schools in particular, have been revealed. These problems include the following: the lack of an effective diagnostic system that would systematically monitor the development of pupils' technical thinking; the lack of an integrated didactic system to form technological thinking in profession-oriented school (as opposed to the university system); the issues on technological thinking characteristics, such as self-regulation, reflexivity and criticality are studied poorly; training courses for teachers, who deliver the subjects, which are directly focused on the technological thinking development, are organized insufficiently. Moreover, the training should be technologically organized in such a way that teachers could develop themselves all the tools necessary to facilitate the formation of technological thinking skills in the upper-form pupils of profession-oriented school.

5. Conclusion

Thus, we have used the methods of solving technological problems of various kinds and complexity as the main educational impact to develop technological thinking skills in the upper-form pupils of profession-oriented school. We believed that successful development of technological thinking of the pupils should be manifested in successful resolution of technological problems, because in the course of solving the problem the pupils demonstrate their creative nature, i.e. criticality, efficiency and reflexivity. Consideration of these indicators makes it possible to perform diagnostics of the technological thinking formation (Zanfirova, 2008).

When solving sufficiently complicated and integrated technical problems, the profession-oriented school teachers and the pupils apply various, sometimes unconventional, the most incredible techniques and methods of solution. In this article, we have given examples of just some of them including *technique on development of the strategy to search for analogies,* "*random substitutions*" *strategy, "real time constraints" strategy, method of sudden prohibitions, brainstorming method, rapid sketch drawing method and method of instructional design.*

The study showed that, firstly, the system of such methods is based on the objective laws of mental development of the pupil personality, prone to technological activities; secondly, these techniques do not require obsessive and annoying solution algorithms, requiring much patience; they just encourage, generate interest and induce pupils towards broad searching and cognitive activities that actually characterizes not only the level of pretentiousness for technology and formedness of technological competency, but also the overall education level of the pupil at profession-oriented school.

6. Recommendations

In our view, the present article is of great value, especially for profession-oriented school teachers specializing in home economics and technology. At that, the teachers should take into account the fact that all the above methods have a common "goal to create conditions providing spirituality formation in pupils, to educate socially adapted creative business persons, having knowledge of the general and technological culture, as well as the technological thinking skills, able to exist harmoniously in the "human-nature", "human-technology" and " human-human" environments (The concept of technological-oriented school, n. d.). It should be recognized that the "technical and technological skills are part of the broader human activity and are essential for the survival of humanity" (Autio & Hansen, 2002).

Including the components, such as divergence, criticality and reflexivity, which, by the way, are developed quite poorly (Planida, 2010), to the technological thinking components, we turn to scientific thinking that can be considered as another recommendation to the teachers. All the more so because the specific features of the scientific thinking are manifested in the course of solving quite complicated and integrated technological tasks and conditioned by peculiarities of these tasks. As is seen from the subject matter of this article, taking into account of all noted indicators allows us to objectively evaluate the success, when solving integrated technological problems and to determine development level of technological thinking skills in profession-oriented schoolchildren.

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