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Technological and methodological aspects of the acquisition of concepts in the process of physics education

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The current paper analyzes some aspects of the problem of forming a concept structure in physics education in secondary schools as a key factor for the quality of the knowledge being acquired. Specific ideas which help the solution to this problem are presented. They refer to the different aspects of the technology and methodology of education, they comply with the current educational trends and together with that they accentuate on the ways of increasing the motivation and cognitive development of students.

Key words: physics education, scientific concept, formation of concepts

INTRODUCTION

One of the most significant tasks of modern physics education is for the students to acquire a knowledge system of physics comprising the basic elements of scientific cognition such as concepts, laws, principles, models, theories, and ideas; students are expected to acquire the aforementioned by means of relations and connections which unite them and make them one whole. It is a well-known fact that concepts are the smallest units in the knowledge system of a science. They present the general and significant properties of objects and phenomena in reality. Furthermore, it is namely the process of formation of conceptual structure in a certain school subject training that forms the foundation of the cognitive development of students, viewed from a psychological aspect. Therefore, the successful solution to this problem is a key factor for the quality of students' acquired knowledge.

Striving against the constantly decreasing interest in studying physics, teachers, in their work, search for and apply various methods, ways and means of increasing the cognitive activity of students. However, the result is not always positive. For one reason or another, one of the preconditions for that, is the fact that not enough attention is paid to the problem of concept formation in the course of studying. Consequently, different aspects of formalism may be found in students' knowledge: memorizing without comprehension; inability to use the learned material for explanation of real phenomena; complete break between knowledge and reality.

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From a pedagogical and psychological viewpoint, the learning process is comprised of "three units:

- The student's knowledge as a product of their education;
- The mental processes by means of which a certain result is achieved;
- The property of the student's reasoning characterizing their cognitive development" [1].

This means that the thing to be sought for in education is the balance between the result and the process of its achievement. Observations, however, show that the emphasis is put on what and how much is acquired, rather than on how it is acquired. The thing that is of great importance is the "correct answer" of the students as a proof of success [2], whereas the issue of what actually happens in their mind, what their personal attitude is towards the experience acquired remains in the background.

It is also important to mention that during the process of knowledge (concept) acquisition, several aspects which are correlative can be categorized, and special attention is to be paid to them in school work:

- Perception (initial comprehension of the material);
- Rationalization;
- Reassertion;
- Mastery (usage of the material in different situations, practical application of the acquired knowledge) [3].

The rational organization of the teaching process makes it necessary for the teacher to search for answers to numerous important questions:

1. What is to be done in order to support the initial acquisition of the new school material and, parallel to that, to facilitate as much as possible

its full comprehension in the process of acquisition? Because, "the acquisition of the material taught is always determined by these preconditions which have been formed up to its comprehension and are also formed in the very process of comprehension" [3]. In this sense, the new school material is to be presented, on the one hand, as a part of a certain knowledge system, i.e. to justify the necessity for its acquisition; and on the other hand, its significant items need to be clearly shown as well as the logical connections with the already learned material to be seen. Therefore, the foundations of comprehension and permanent learning of the material are laid precisely at the initial acquaintance of the students with it.

2. What additional work is to be done in order to further reveal the contents of the school material in detail? The result of that is strongly influenced by the features and quality of explanations the teacher gives in the process of studying. These explanations are to be built and analyzed from a psychological viewpoint and the possibilities should be recognized for their remembering. This is how the matter of repetition in the school process arises, with the accent put not on the simple mechanical reproduction, but on such repetition of the material which is related to its recurring, remodeling, understanding and even re-understanding. This is the way to successfully influence not only the comprehension of the school material but also the permanent "engraving" (reassertion) of knowledge in students' minds.
3. What specific work is to be done in order to form the students' ability for practical application of knowledge, namely the ability to operate with the acquired material in various theoretical and practical situations, assigned through concrete cognitive problems? In this case the basic aim is for students to get involved into active, life-motivated activity, where the formation of practical abilities and habits is combined with the acquisition of new aspects, new characteristics of already acquired competences, with the result of these competences to be turned into a means of knowledge.

The analysis of the examined theoretical formulations shows that what is of great importance for the adequate and permanent acquisition of knowledge (concepts) in the process of physics education is not only the way of elaborating the school material but also the characteristics of the cognitive activity which students are involved in. These are basic factors which show to what extent students can master mental processes, such as analysis, synthesis, comparison, systematization, disregard, generalization, concreteness, without which the acquisition of knowledge is impossible. This is so because in order to be acquired knowledge needs to be understood first, and the way scientific information is processed in students' minds lies in the basis of understanding, that is, all in all, understanding is directly connected and dependent on the level of formation of the scrutinized cognitive operations. Therefore, concept acquisition in physics education has inevitably to be a result of purposeful and various cognitive activities of students, whereas the way teachers create the necessary conditions for that depends on their professionalism and their ability to be innovators and creators in school work.

PRACTICAL ASPECTS OF CONCEPT ACQUISION

Teachers can obtain some very useful feedback about how their students acquire concepts if they carefully analyze the mistakes they make in different school situations. One can, for example, assign the following task: A motorcyclist has passed the first half of a certain distance with speed rate of 30 m/s, and the second half – with 15 m/s. Find the average velocity of the motorcyclist. Observations show that a great number of students immediately give the wrong answer, which is 22.5 m/s, without preliminary analyzing the task in advance. What they do is calculate the average velocity, corresponding to the separate distances. This very simple example makes it possible to draw several conclusions. It is obvious that the students do not understand the concept *average velocity*. This is the reason why students cannot distinguish between the above mentioned concept and the concept *arithmetic mean of velocity* and therefore experience difficulty applying it in the new conditions given in the physical situation in the problem. What one can see is a considerable blunder in teachers' work: they have not done the necessary, they have not created the preconditions which contribute to the perception, rationalization, understanding and reassertion of the concept; and, naturally, students cannot operate with it, they have problems with its practical application.

The first step teachers can perform in such a situ-

ation is to ask their students to give a definition of the concept of interest. This includes a concrete verbal formulation of the concept as well as a written definition of the formula. It is appropriate for the analysis to be like a discussion where the whole class participates. This situation will help the teacher to notice the failures of their students because this activity will result in finding those who: give a concrete definition of the concept verbally, but cannot write the formula which defines it; write the definition formula correctly but cannot explain the concept; define the concept impeccably not only verbally, but also using the formula. Naturally, there are cases of students who cannot perform either task. Then, analogically, the basic idea of the concept *arithmetic mean of velocity* is to be clarified and after that to start solving the problem and it is again advisable that each step be discussed with the whole class. It is essential, in the end, that the teacher accentuate on the following: calculating the average velocity as the arithmetic mean of the average velocities, corresponding to different parts of the motion, without any connection with the definitive formula of this physical quantity, means to transfer incorrectly the mathematical concept *arithmetic mean of several numbers* to the context of a particular physical problem.

Therefore, a question arises: What can teachers do in order to restrict the occurrence of such mistakes? Firstly, they should think carefully about the way to introduce each concrete concept. In accordance with [4] for most concepts that are taught at school, it is most useful for a definition to be given fist, followed by several examples and then the definition should be elicited again, showing how the examples characterize the definition. Therefore, in this particular case, the teacher should perform the following actions: substantiating the necessity to introduce the concept *average velocity* as a characteristic of non uniform motion; giving a concrete definition of the concept with words and a definition formula; showing examples of non uniform motion, connected with the calculation of average velocity; going back to the definition and accentuating on the physical sense of the definition formula.

From a psychological viewpoint, it is of great importance for the thoughts of the students to be brought back again to the acquired concept at the later stages of the study process. These phenomena are also known as current and general repetitions. In order to show the current repetitions, the teacher should choose informative problems which require the use (application) of the concept in various physical situations, different from those the concept was initially introduced in. In this way, the redefinition of the studied material is realized, but this happens under new conditions and the necessary prerequisites are met for the detailed understanding and reassertion of knowledge. The general repetitions are related to the systematization of concepts. In this particular case, this means that the relations and inter-dependence between the concept *average velocity* and all other kinematic characteristics of motion are to be shown. Therefore, the above presented problem can be given to students to solve at a later stage of their study process as an element of current repetition. This can be done after teaching the uniformly-variable motions when students already know that with this type of irregular motion the velocity changes with one and the same value for equal intervals and therefore the average velocity can easily be calculated in another way using the definition formula: it is equal to the arithmetic mean of velocity at the beginning and velocity at the end of the considered interval. At that stage it is appropriate for the teacher to check the extent to which students are prone to make the mistake mentioned above.

It is important to point out that the choice of this example is not arbitrary. It directs the attention of the teacher to the opportunity to use comparison as very helpful practice for formation of concepts. What is more, in this specific case, the matter concerns the comparison of concepts from different subject areas – physics and mathematics; and it is well-known that the math preparation of students is of primary importance for physics education. That is why, finding and analyzing the relations and dependence between such concepts has to be a compulsory element in the teaching process.

Other recurrent mistakes may be stated if students are given various problems requiring classification of already studied concepts. This method is very productive for physics education because "classification is what gives our way of thinking strictness and concreteness" [5]. For example, the teacher can prepare a number of concepts and ask students to analyze them in two groups: concepts of physical phenomena and concepts of physical quantities. The result of this activity mostly depends on the extent to which students are ready to answer the question: What is necessary to know about physical phenomena and physical quantities? It is an irrefutable fact that student's

course books do not give a definition to these concepts and teachers do not pay such close attention to them, as they presume that their idea can be clarified only by means of concrete examples. The frequency of students' mistakes, however, shows that this is not enough. How can one help the solution to this problem? Talking from a psychological and methodological viewpoint, it is helpful for the teacher to use general didactic models in the teaching process. These models reflect the specific logical structure of the activity employed in acquiring each of the examined elements of the scientific knowledge and play a vital role as an outer support in the formation of the inner mental processes of students. For example, the summary of a physical phenomenon studies shows the structure typical of phenomena studies in science, and it consists of the following steps [5]:

1. Finding the external characteristics of a phenomenon.
2. Clarifying the conditions under which it occurs.
3. Analyzing the phenomenon in laboratory environment (if possible) or getting acquainted with the results of such analysis.
4. Defining the physical quantities which characterize the phenomenon and presenting the connections between them (by means of formulas, graphs, etc.).
5. Defining the phenomenon (clarification of the essence of the phenomenon, its inner course on the basis of popular physical theories).
6. Clarifying the connections between a given phenomenon and others.
7. Scrutinizing the most important uses of the phenomenon in practice.

The summary of quantity characteristics of physical objects studies, which is physical quantities, consists of the following steps [5]:

1. Clarifying what property of the physical object characterizes a given quantity.
2. Giving the definition of the term quantity.
3. Writing of the definition (definite) formula. Finding out whether the quantity is basic or derivative, whether it is a vector or scalar quantity.
4. Revealing the physical sense of the quantity.
5. Defining the measurement units.
6. Clarifying the ways of measurement (measurement procedures).

Importantly, it is not enough for these general schemes to be merely explained to the students. It is necessary for the teacher to show how the schemes are applied in practice, i.e. to present the activity of concept acquisition of concrete physical phenomena and quantities. The method of teaching is also of great importance; the way it comes to realize the separate logical steps in the school process in accordance with their specific traits, enabling students to apply the examined models on their own, using them as a point of orientation when acquiring new concepts; teachers can use these models to check how detailed students' knowledge about a certain phenomenon or quantity is. This is the way to form the necessary preconditions for appropriate grouping of each concrete physical concept into one of the two categories. In the language of logic this means the following: suitably realized operation of categorization of concepts in which the range of the generic concept (the number of objects included in a given generic concept) is sub-divided into specific concepts.

Apart from comparison, systematization and classification, teachers can use another helpful method of concepts acquisition: put the students in a situation where they have to determine the difference between similar concepts [6]. What does that mean? It is frequent practice for teachers to ask the same questions at different stages of education, aiming at reassertion of students' knowledge. An example of this is: Which process do we call heat transfer? In this situation, the way the question is asked presupposes an answer which requires recollection of material taught and in this case what comes to be examined is the memory of students. Therefore, even if the answer is correct, it does not necessarily mean that the concept is understood. However, the situation would be completely different if the teacher asked the question: What is the difference between heat transfer and thermal conductivity? In this case the student's answer is the result of specific cognitive activity.

This example shows that it is of primary importance for the teacher to ask questions which urge students to think about the concepts. Furthermore, teachers should stimulate their students to perform this action on their own, i.e. students are to generate similar questions to themselves and to their classmates.

There are exercises, which are interesting and innovative, related to the concretization and generalization of concepts [6]. These are logical operations of transition from a generic to a specific concept and vice versa. Let us say, for example, that the following concepts are given: heat transfer; physical phe-

nomenon; heat phenomena with solid bodies; thermal conductivity; heat phenomenon. In order for the operation of concretization of concepts to be performed, they are to be arranged in the following logical succession: physical phenomenon; heat phenomenon; heat phenomena with solid bodies; heat transfer; thermal conductivity. The generalization of the concepts requires that they be arranged in exactly the opposite succession.

CONCLUSION

It is an unarguable fact that the problem of concepts formation in physics education is extremely complicated and always of present interest. In order to solve it, teachers should find the answer to the fundamental question: How, or so to say, in what way are students to acquire systems of scientific concepts in the school process? This question does not have an unambiguous answer. It urges teachers to perform two important tasks: 1) to develop and improve their knowledge about the problem by getting acquainted with some basic as well as general theoretical formulations in the field of psychology, logic, pedagogy, etc. and 2) to search for adequate practical realization of these formulations in school work, while having in mind the age peculiarities of students and the features of the educational content. In this way, teachers find themselves in a very complicated situation because, on the one hand, the theoretical views upon the subject are diverse and numerous and teachers cannot easily find their way; and on the other hand, the solution to the second task makes teachers ask many additional questions connected with the organization of the teaching process, the methods of presenting the school material, the choice of cognitive problems. Due to the abovementioned issues, teachers cannot always create favorable circumstances which will contribute to a detailed and permanent concept acquisition. As a result, they are faced with the respective negative consequences. Concept acquisition for some students turns into memorizing words. They do not understand the essence of concepts, they find it difficult to see the connections and dependence between them and, in the end, students cannot see concepts as structural elements of a given system. Consequently, such students are unable to use the systems of concepts when acquiring new knowledge. This is the path which leads to loss of interest and motivation for school work and alienation from the school process.

What should teachers accentuate on in the organization of this complex cognitive activity? They have to create the necessary environment for multi-faceted adaptation of the scientific information students obtain during their study process. This means that the new knowledge (concepts) has to be presented in such a way that its acquisition demands as much active reasoning on part of the students as possible. This is an effective way of improving the quality of students' knowledge. On the other hand, during the acquisition process the change of knowledge is accompanied by a change in the structure of the mental processes by means of which these competences are realized. Thus, teachers can develop the theoretical thinking of their students.

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ТЕХНОЛОГИЧНИ И МЕТОДИЧЕСКИ АСПЕКТИ НА УСВОЯВАНЕТО НА ПОНЯТИЯ В ОБУЧЕНИЕТО ПО ФИЗИКА

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(Резюме)

В доклада се анализират някои страни на проблема за изграждането на понятийната структура в обучението по физика в средното училище като ключов фактор за качеството на усвояваните знания. Предлагат се конкретни идеи, подпомагащи решаването на този проблем. Те касаят отделни аспекти на технологията и методиката на обучение, съобразени са със съвременните образователни тенденции и поставят акцент върху възможностите за повишаване мотивацията и развиване мисленето на учениците.