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Methods of forming physical concepts for primary school students

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Abstract

Improving the education quality, its compliance with modern requirements is closely related to the assimilation of scientific concepts by schoolchildren, which is one of the most important components of the scientific knowledge element. The article aims to present a methodology for the students' formation of physical concepts. The stages of mastering the concepts are also shown in the article. The results of a pedagogical experiment reflecting the effectiveness of the proposed methodology are presented. The effectiveness of the proposed methodology was tested in a pedagogical experiment. The pedagogical experiment was conducted at 3 schools in Kazakhstan, control classes of 60 students and experimental classes of 56 students were taken for the pedagogical experiment from the 10th grade. A total of 116 students took part in the pedagogical experiment. The results of the study evinced that students' high-level knowledge is determined by the level of assimilation of physical concepts, an important component of the physical knowledge elements.

Keywords: mastering concepts; physics; physical concepts.

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1. Introduction

One of the main tasks of teaching is to ensure that schoolchildren master concepts. Schoolchildren's assimilation of concepts is the basis for careful assimilation of problem material and the ability to apply the acquired knowledge to various situations (Komogorova et al., 2021). The quality of schoolchildren's knowledge depends on the level of scientific concepts formed in them since the concept is one of the main components of scientific knowledge. From this point of view, schoolchildren's assimilation of scientific concepts is one of the most pressing problems.

The experience accumulated by mankind over many centuries is reflected in concepts. Each concept consists of a system of interrelated concepts. Pedagogy defines scientific concepts as the main structural unit of the education content, based on their gnoseological and psychological significance in the cognitive process (Zhumash et al., 2021). The reason concepts are the main structural element of scientific knowledge is: first, due to the logical and gnoseological role of the concept, the relationship between concepts. After all, concepts and the connections between them, truly reflect reality, the content of things and phenomena. Secondly, it depends on the psychological meaning of the concept.

1.1. Theoretical background

Various ways of forming physical concepts for students are shown in the works of E.Mambetakunov, E.A.Akkoshkarov, M.Kudaikulov, Yu.V.Kazakova, K.S.Shadinova, U.N.Sultonova, etc. Mambetakunov (2015a) shows the need to use a system of exercises at the initial stage of the formation of physical concepts. «Matter», «motion», «matter and field», «mass», «work», «energy», «electric charge», «atom», «molecule», «elemental particle», etc., such similar concepts are the basic concepts of all sections of the physics course. These concepts are also important in teaching other natural sciences, in particular chemistry, biology. The didactic function of interdisciplinary communication in the formation of student's concepts of Natural Sciences was considered by Mambetakunov (2015b) in his work «Didactic functions of interrelated relations in the formation of learned natural concepts» . He showed ways to implement interdisciplinary communication in the formation of concepts of Natural Sciences.

In his work Akkoshkarov (1976) identified some ways of forming physical concepts, and the methodology of teaching individual chapters and topics of the school physics course and the formation of some basic concepts is indicated in the work of Kudaikulov (1998). Mamedov & Azerbaijan, (2021) analyzed the concepts of «inertia» and «inertial» in the school physics course. He points out that to date; there is no generally accepted methodology for the formation of these concepts in the educational and methodological complexes on physics.

Shadinova (2009) in her scientific work raised the problem of forming the concepts of electronics in the school physics course. Sultonova (2019) in teaching physics there are several theoretical and practical methods, the most important is the problem solving of physics,- points out in her work. It is possible to form and develop students' logical and creative thinking skills by solving physics problems. Solving problems contribute to deeper and more solid assimilation of physical laws, the development of logical and creative thinking.

The problem of forming intermediate physical concepts for Primary School students on the example of the subject «Natural Science» is raised in the works of Berkeley et al., (2017). Students do not master other elements of scientific knowledge (theory, laws, rules, research methods, etc.) without mastering interdisciplinary scientific concepts. This is because scientific concepts are the main structural element of scientific knowledge. One of the most effective ways to form schoolchildren's physical concepts can also be attributed to computer modeling of physical phenomena and processes. It is possible to improve the quality of teaching physical phenomena and processes by using the method of computer modeling. The use of computer modeling in the study of physical phenomena and processes is considered in the works of Berkinbayev et al. (2017) . Computer modeling of physical phenomena and processes is considered in the work of Berkinbayev, which is the main priority of using information technologies in physical education. One of the most important tasks of teaching physics is to form ideas about the structure of matter. It is also important to use the method of computer modeling in an in-depth explanation of the meaning of physical phenomena and processes to students.

Features of the formation of complex concepts in the basic school physics course are considered in the work of Koloskova (2016). At the same time, he identified the features of the formation of the concepts of «mass» and «force», the stages of the development of the concepts of «mass» and «force». Despite a large number of studies, this problem is devoted to the process of forming students' physical concepts, it still requires a complete solution. With an overview of some ways of forming physical concepts for schoolchildren and scientific and methodological works on the issues of deepening and improving the teaching physics course, we offer schoolchildren a methodology for forming physical concepts. Because changes that are currently taking place in school curricula require a revision of the methodology of teaching physics at schools, in particular, students' high-level assimilation of physical concepts.

1.2. Literature review

1.1.1. Methods of formation of physical concepts

The process of teaching physics is closely related to the formation of scientific ideas in the minds of students, which is an integral part of the physical representation system. The effectiveness and correctness of the formation of students' physical representations directly affect the success of the process of teaching physics in general. It is known that each concept is in a certain relationship, in a certain relationship with all other concepts. Therefore, in science, the development of each concept takes place not separate from others, but in close contact with each other. This is directly related to the learning process because the concept does not lie in the student's head like a frozen chain next to each other. In other words, students' scientific concepts are formed not in isolation, but the form of interconnected systems.

The process of teaching physics is the system formation of students' physical concepts. Mastering concepts is one of the most basic components of the process of mastering knowledge. This is because mastering physical knowledge means, first of all, mastering a system of physical concepts (Usova, 1969). Since the content of the school physics course is a system of interrelated concepts, the main task of the physics course is to form a system of concepts.

From the didactic point of view, the concept can be defined as the knowledge of the essential properties of phenomena and objects, significant connections, and relations between them. First, individual concepts are formed, then a system of concepts is formed. Thus, the process of forming concepts consists of a system of revealing the quantitative and qualitative properties of objects and phenomena, bringing them to dictionary definitions, and consciously applying them in practice. The methodology for forming physical concepts is shown in Figure 1.

The proposed methodology for forming physical concepts includes the following components (Sydykova, 2015):
- methods of mastering physical concepts by schoolchildren;
- stages of mastering physical concepts;
- equipment used in the study of physical concepts;
- forms of training sessions organized for mastering physical concepts.
-These components are divided into elements.

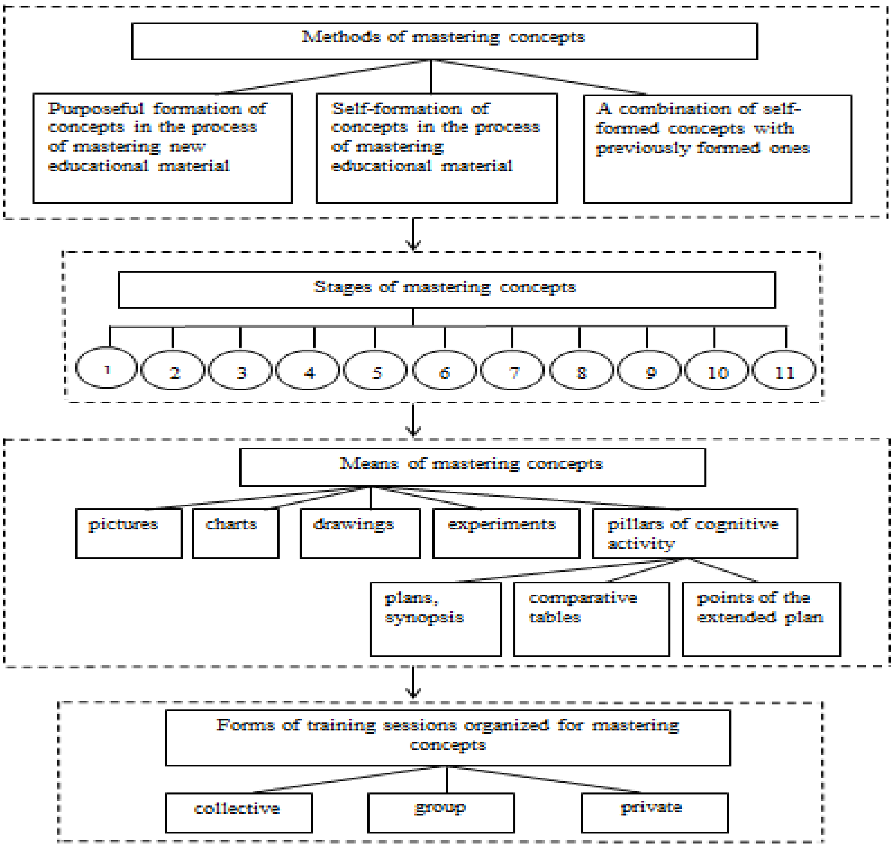
-The following methods of mastering physical concepts by schoolchildren are considered:
- purposeful formation of concepts in the process of mastering new educational material;
- self-formation of concepts in the process of mastering educational material;
- a combination of self-formed concepts with previously formed ones.

1.1.1.1. Methods of mastering physical concepts by schoolchildren

Often, in the process of interpreting new educational material, the self-formation of concepts is accompanied by purposeful formation. Here, the purposeful formation of concepts is based on the result of self-formed concepts, on the daily experience of students, and begins with the consideration of known facts and phenomena. The organization of purposeful formation of concepts depends on the availability of students' first knowledge of the concept and the ability to apply it to a new topic.

Figure 1

Methodology of formation of physical concepts



The organization of self-formation of a concept in the assimilation of educational material and the purposeful formation of a concept in the process of repeating new material depends on the formation of concepts that have no analogues in the everyday experience of students. Here, the teacher first organizes the spontaneous formation of a concept in students, and then, through the process of repeating it, the combination of concepts with the purposeful formation.

1.1.1.2. Stages of mastering physical concepts

The next component of the proposed methodology is the stages of mastering concepts (Iten et al., 2020). This includes:

1. Sensory-real perception-takes place in various situations (observation of phenomena at home, at school, in life). Observation of objects during the teacher's demonstration of frontal experiences to identify the properties and external features of phenomena; working with textbooks; working with distributed materials (cards); analyzing facts, etc (Hansson, Leden & Thulin, 2021). Sensory perception is targeted in a school setting. Here the teacher allows the students to distinguish certain properties of the observed object. It is carried out by analyzing, comparing. At first, students observe only one object, for example, an increase in the level of liquid when heated. It is also possible to observe how students increase the volume of several different liquids by heating them.

2. The distribution of properties common to all controlled objects in the example above is a common feature for all controlled liquids - this is an increase in the volume of the liquid when heated. By observing liquids when heated, students conclude that «all liquids increase when heated». You can also control the increase in the volume of solid particles when heated. From this, the students come to the general conclusion: «When heated, the volume of all bodies (solid, liquid, and gaseous) increases».

3. Distinguish between minor properties of a controlled object and minor properties (abstraction). In this example, the name (term) «thermal increase» is introduced to denote the common value properties of all bodies. For all substances, regardless of their state (in a solid, liquid, or gaseous state), «thermal increase» is a significant property. It is necessary to distinguish this value from a property without a property value. For example, liquid can be poured into dishes of different shapes or taken in different volumes, etc. even in all cases, their volume increases during heating. The same principle applies to solid bodies (Venkateshan, 2022).

4. Definition of the concept. At this stage of mastering the concept, students are instructed to give a definition indicating the genus and species features of the new concept. In the example discussed in the previous section, the parent concept is a «phenomenon» (more precisely, a «physical phenomenon»), and the species concept is an increase in body volume during heating. So, the definition of the concept: «Thermal increase means an increase in the volume of the body when heated».

5. Remember and identify the main features of the concept (by performing a system of exercises). The solution to this problem is carried out by performing a specially created system of exercises:

a) exercises for changing the expression of non-essential features of the concept in various forms;
b) exercises to select the most important features of a concept from the given features;
c) Exercises for creating a reverse problem;
d) qualitative questions that require defining a concept or specifying its essential features.

6. Establishing the relationship of a given concept with another concept is carried out by various methods, depending on the type of concept. In the process of forming concepts about phenomena, experiments are conducted or observations are organized. For example, it is proved by experiments and observations that the rate of drying (evaporation) of a liquid depends on the size of the free surface of the liquid and the temperature. For example, when mastering the concept of boiling point, it is recommended to assign students that the temperature of the liquid does not change during boiling. After the demonstration practice developed by the teacher, he will master the dependence of boiling point on pressure.

7. Application of the formed concept in solving problems within the framework of only one discipline.

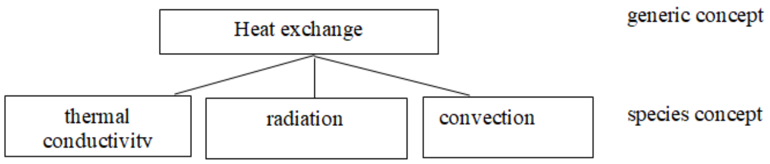
The goal of this stage is to teach students how to apply concepts in other situations, such as problem-solving. It is accompanied by the consolidation of students' knowledge and the establishment of connections and relationships between previously acquired concepts and newly formed concepts.

8. Classification of concepts. The purpose of this stage is to establish the relationship and relationship of the acquired concepts, generalize and summarize knowledge. For example, when teaching the phenomena of heat exchange and evaporation, students can be given the following tasks:

1)Determine the relationship between the concepts of «thermal conductivity», «heat transfer», «radiation», «convection». Show the concept of origin and its types, and illustrate their relationship using the diagram below (Figure 2).

Figure 2

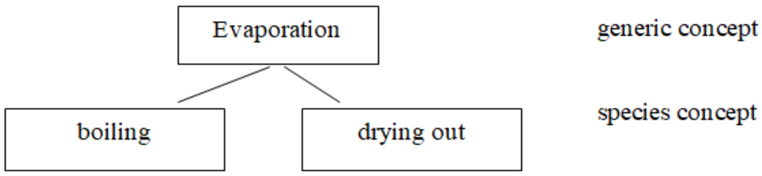
relationship between the concepts



2) determine the ratio of the concepts «boiling», «evaporation», «drying out» and show them using a diagram (Figure 3).

Figure 3

Determining the ratio of the concepts



9. In the process of mastering a new concept, it is necessary to rely on the given concept. For example, when mastering the concept of thermal motion, it is possible to explain the main features of mechanical motion by comparing them (Leden & Hansson, 2019).

10. Establishing new connections and relationships between a given concept and another concept.

The essence of this stage is that the concepts that are formed and continuously developed are in New, somewhat broader connections with the concepts that are formed in the process of teaching new topics or new sections of the course, as well as in the course of teaching other disciplines.

11. Application of concepts in solving problems of a creative nature. Ability to solve problems; establish connections and relationships between concepts of different topics, chapters, as well as different disciplines; be able to explain how phenomena go through changes in conditions in the report; be able to create a new version of the experience to demonstrate a given phenomenon, etc (Ceuppens et al., 2019).

1.1.1.3. The tools for mastering concepts

The next component of the proposed methodology is the tools for mastering concepts. Tools for mastering concepts include auxiliary materials used in the process of mastering concepts. These tools include drawings, graphs, drawings, experiments, and supports of cognitive activity according to the material being read: plans (synopsis), comparative tables, plans of a generalized nature, etc. Since drawings, graphs, drawings, and comparative tables are used daily in the educational process, we will not dwell on them. In our opinion, we decided to explain the method of drawing up a plan (synopsis), which we found to be more recent, and plans of a generalized nature.

The method of drawing up a plan (synopsis) involves dividing the material into parts and reference points according to their meaning. Reference points contain certain content. They can be of various forms: individual words, sentences, drawings, drawings, patterns, etc. The ability to distinguish supporting signs contributes to better assimilation of educational material and its long-term memorization.

Plans of a generalized nature (extended plan) are a set of questions that are arranged in a certain system and indicate what the main one in the given text is. Plans of this nature form the ability to distinguish the main ones, values of what they read, find answers to the main questions in the textbook, and so on. Effectiveness of working with generalized plans: thanks to the independent search of students, the educational material is remembered for a long time, and they master concepts well. The result will be higher if the formation of concepts is carried out using such visual means, and not with bare words.

1.1.1.4. Forms of training sessions organized for mastering concepts

The next component of the proposed methodology is the forms of training sessions organized for mastering concepts. The forms of training sessions organized in the development of concepts are divided into collective, group, and individual. The components are shown in Figure 1 act on each other and interact with each other.

The purpose of the proposed methodology is to increase the effectiveness of students' assimilation of physical concepts. The methodology, which increases the effectiveness of students' assimilation of physical concepts, consists of a set of closely related components that pursue a common goal.

1.2. Purpose of study

The process of teaching physics is a set of interrelated activities between a student and a teacher, which allows students to master the basics of this science consciously and firmly, teaches them to use the acquired knowledge in practice and life. The process of teaching physics, pursuing an educational goal, describes the relationship between the following components:

a) the training content is to teach students the content of physics;

b) teaching is a teacher’s ability to explain the lesson using physical experiment, technical means, organize and lead students’ independent work, test students' knowledge and skills;

c) learning is a variety of educational skills that include mental and physical students’ activities (specially organized observations and laboratory experiments play a special role in mastering physics);

d) material condition for training (textbooks, report sets, instruments, technical means, tables, etc.).

Improving the education quality, its compliance with modern requirements is closely related to the assimilation of scientific concepts by schoolchildren, which is one of the most important components of the scientific knowledge element. The article aims to present a methodology for the students’ formation of physical concepts.

2. Materials and Methods

2.1. Data collection tool

The effectiveness of the proposed methodology was tested in a pedagogical experiment.

2.2. Participants

The pedagogical experiment was conducted at 3 schools in Kazakhstan, control classes (N=60 students) and experimental classes (M=56 students) were taken for the pedagogical experiment from the 10th grade. A total of 116 students took part in the pedagogical experiment.

2.3. Procedure

To master students' concepts effectively, the teacher must know the signs and conditions of their formation, we were guided by the recommendations of scientists. Therefore, we have taken the following as a sign-condition for students to master physical concepts efficiently:

-know the main features of the concept and can freely formulate its definition;
-know the relationship and relationship of the concept with other concepts;
-can distinguish the essential features of the concept from the unimportant ones;
-can use the concept in the process of solving various cognitive and practical problems.

To assess the degree of assimilation of formed concepts by students following these acquired criteria, the following indicators are assigned:

- have knowledge of the phenomena described by the concept;
- know the main properties of the concept;
- can freely formulate its definition;
- can associate a concept with another concept;
- can show their differencesby comparing a concept with another concept;
- can describe phenomena using the concept;
- know the unit of measurement of a concept and can measure it;
- can write the basic formula depending on the concept;
- can create standard problems related to the concept.

Depending on the indicators given as a result of the pedagogical experiment, 4 groups of students' level knowledge of concepts were identified: High, good, medium, and low (Bugaev, 1981; Sydykova, 2015).

Level 1 (low): students can only distinguish one object from others, but they cannot show its individual characteristics.

Level 2 (average): students can show signs of concept, but they cannot distinguish meaningful signs from meaningless ones.

Level 3 (good): students have mastered all the essential features, but the concept has not yet been generalized.

Level 4 (higher): the concept is generalized, students know the relationship of the concept with other concepts and can use it for any situation.

3. Results

In the course of the pedagogical experiment, classes in experimental classes were conducted according to the proposed special methods. That is, in the process of forming physical concepts in experimental classes, we were guided by the stages of forming concepts, methods of mastering physical concepts by schoolchildren, and plans of a generalized nature.

In the course of the pedagogical experiment, control and experimental 10th-grade students received formative control after passing each topic throughout the experiment and summary control at the end of each section, the results of which were analyzed. The results were compared and individual work was carried out with students on shortcomings. The result of determining the level of students' knowledge of concepts before and after the experiment is shown in Table 1.

Table 1

Determining the level of students' knowledge of concepts before and after the experiment

Level of knowledge of concepts	Before the experiment		After the experiment	
	Control class (%)	Experimental class (%)	Control class (%)	Experimental class (%)
1	13,33	14,29	8,33	1,79
2	16,67	16,07	31,67	10,71
3	46,67	46,43	33,33	48,21
4	23,33	23,21	26,67	39.29

The levels of assimilation of physical concepts by students of control and experimental classes before and after the experiment are shown in Figures 4 and 5.

Figure 4

Control over the assimilation of concepts by students of the class levels (number of student's % given)

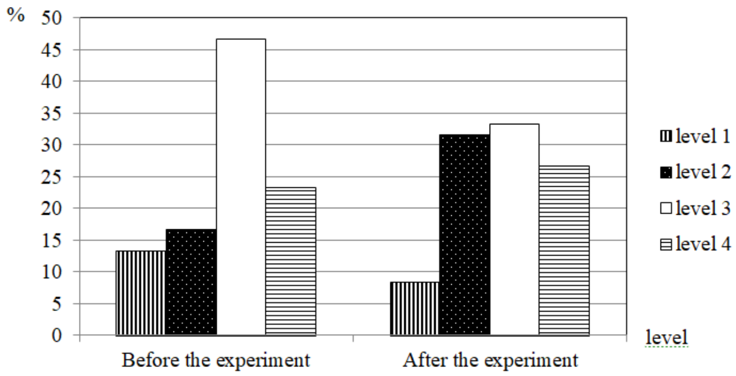
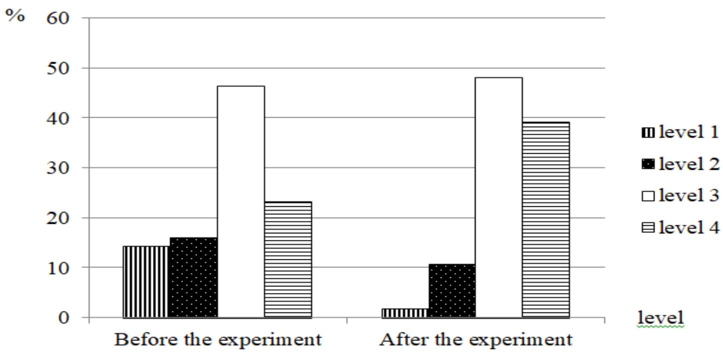


Figure 5

The students' ability of experimental classes to master the concepts of levels (number of student's % is given)



The results of the pedagogical experiment show that the students' knowledge level of the experimental students constantly increased in comparison with the control students. At the beginning of the pedagogical experiment, the student's knowledge level of experimental and control classes was similar. After the experiment, the students' knowledge level of the experimental class increased considerably. In particular, before the experiment, in the experimental class, there was a low level (1) – 14.29 percent (8 students out of 56 students), after the experiment – 1.79 percent (1 student out of

56 students). And the high level was 23.21 percent before the experiment (13 students out of 56 students), after the experiment – 39.29 percent (22 students out of 56 students).

To determine the effectiveness of the proposed methodology in the pedagogical experiment, The Kramer-Welch criterion was used (Novikov, 2004). The Kramer-Welch criterion was calculated using this formula $T_{\text{emp}} = \frac{\sqrt{M \cdot N}\left|\bar{x} - \bar{y}\right|}{\sqrt{M \cdot D_x + N \cdot D_y}}$ (1). The empirical value of the Kramer-Welch criterion was calculated using the average values ($\bar{x}$, $\bar{y}$)and variances (D_x, D_y)of tasks performed correctly by students of the N control and M experimental classes. Variances $D_x = \frac{1}{N-1}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)^2$ and $D_y = \frac{1}{M-1}\sum_{i=1}^{N}\left(y_i - \bar{y}\right)^2$ calculated using formulas.

To determine the effectiveness of the proposed methodology, the students'experimental knowledge level of the control and experimental classes was first determined. For this purpose, control works were given to students in control and expert classes. Based on the control work results, the number of tasks that students in the control and experimental classes correctly completed before the experiment was determined. Then the value T_{emp} was calculated using Formula (1). Before the experiment, $T_{\text{emp}} = 0{,}04$ was equal to, which is less than the crisis value $T_{\text{emp}} \leq T_{\text{cr}}$, the crisis value of 0.05 is equal to $T_{0{,}05} = 1{,}96$ according to the significance.

After the pedagogical experiment, $T_{\text{emp}} = 2{,}98$ was equal, 0.05 significance experimental value of the Kramer-Welch criterion according to the level above the critical value, i.e., $T_{\text{emp}} \succ T_{\text{cr}}$, it can be seen that the pedagogical experiment gave a positive result.

4. Conclusion

Understanding from a psychological point of view means identifying the features of the studied phenomena and objects, identifying their essential features is the basis of analysis and selection, inference, establishing similarities and differences between concepts. Thinking is the ability to use concepts. If a student understands what properties a substance has, what is concerning and concerning other substances, and what its difference from it is, then the student has an idea of the substance in question.

The students' high level of knowledge is determined by the level of assimilation of physical concepts, an important component of the physical knowledge elements. Because it is impossible to master laws and theories without mastering physical concepts. Mastering laws and theories imply a connection between physical concepts. Therefore, in the research course, the main stages of formation of physical concepts, signs, and conditions, indicators, and levels of students' assimilation of physical concepts were determined by the analysis of methodological works.

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