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THE MODERN PARADIGM OF HUMANITIES EDUCATION: PHILOLOGICAL AND PEDAGOGICAL ASPECTS, FROM THEORY TO EDUCATIONAL PRACTICES AND INTERDISCIPLINARY RESEARCH

Collective monograph

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SECTION 5. SECONDARY EDUCATION

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5.1 The history of the development of methods for organizing and conducting classroom-based laboratory experiments in physics in secondary schools

The development of general secondary education in Ukraine at this stage is focused on modernizing the educational process in line with leading global trends and societal needs. One of the key areas of this modernization is the introduction of innovative pedagogical approaches, digital learning technologies, modern information and communication tools, as well as the application of the latest scientific and methodological achievements in school education.

In the context of physical education, the experimental component of learning takes on particular significance, since physics is a fundamental natural science, whose development is based on observation, research, and experimentation. That is why one of the priority tasks of physics teaching methodology is to improve the system of educational physics experiments, particularly students' laboratory and practical work. Important aspects of this process include raising the level of scientific rigor and research orientation in students' experimental activities, fostering their cognitive independence, and developing critical thinking, creative abilities, and research skills.

At the same time, improving the forms and methods of teaching physics is impossible without a thorough analysis of scientific and pedagogical experience and the historical development of teaching methodologies. Studying the evolution of approaches to organizing physics experiments in the classroom allows us to identify trends that meet contemporary standards for the quality of general secondary education and also provides a scientific foundation for the further reform of school physics education.

This fully applies to physics laboratory work, which is traditionally regarded as one of the main forms of organizing students' experimental activities. Despite a significant number of scientific and methodological studies devoted to issues of their content, methodology, and didactic potential, the history of the formation and development of laboratory work in the school physics curriculum has not yet been sufficiently covered in educational science.

When analyzing the historical development of laboratory experiments in physics education, it is important to note that physics emerged as an independent science only in the mid-18th century, having separated from natural philosophy and developed its own subject matter, methods, and research objectives. In the 18th century, physics began to be systematically taught at universities, and by the late 18th and early 19th centuries, it gradually became part of the high school curriculum. It was during this period that the school physics experiment began to take shape as an important component of physics education.

In schools in the United States and England, earlier than in schools in other countries, new trends in physics education were introduced with persistence, primarily of a methodological nature, namely, bringing teaching methods closer to the practical application of natural science knowledge.

In the United States, a list of school laboratory exercises published by Harvard College in 1887 played a decisive role in the reform of physics education. It contained guidelines for laboratory classes. This list became one of the driving forces behind the organization and spread of the laboratory method in physics education. This movement was so successful and became so widespread that in 1898, the "Commission of Ten," which was established by the "National Association of Education" to discuss and resolve issues in secondary education, was already able to formulate, among other theses, the idea that the teaching of physics and chemistry should consist of laboratory sessions, textbook study, and teacher explanations, with half of all class hours devoted to laboratory work.

The purpose of laboratory work, as defined in the instructions for the Harvard List, was as follows: "To achieve the course's objectives, the student assumes – whenever possible – the role of a researcher working in an unexplored field of phenomena during laboratory work. But this position, if strictly adhered to, would either require the student to spend an unreasonably long time studying a single group of phenomena, or would lead him to develop a habit of superficial and hasty generalizations. He should be required to work carefully, but the degree of precision must correspond to the instruments and time at his disposal, and no more than that. One should not tell him in advance exactly what he must observe, but, of course, he must be told in which direction he must work. He must be taught to draw conclusions from his own experiments, but he should be shown the sources of possible and inevitable errors in his work, to save him from the dangerous mistake of thinking that all so-called laws are derived from experiments just as superficial as those he himself performs. Indeed, the greatest value of a student's conclusions lies in the fact that they enable him to understand and, without placing excessive demands on his faith, to accept the generally accepted conclusions of physicists – and these conclusions, in the end, must be imparted to him" [176].

As can be seen from the Harvard list, the emphasis is on practical knowledge of facts and laws, with a view to their usefulness for the thinking and activities of educated people. In 1889, the "Commission on College Entrance Requirements" argued that laboratory work should contribute to a clear and coherent understanding of the most important facts and laws of elementary physics.

Beginning in 1884, Professor Armstrong, through his lectures and articles, sparked a movement in the English educational world aimed at introducing the heuristic method.

In the teaching of physics and chemistry, the heuristic method manifested itself in the fact that the focus of studying these sciences was shifted from the classroom to the laboratory. Only the most complex demonstrations, preliminary analysis of the problem, and final generalization remained in the classroom. The entire development of knowledge and the progression of the course took place in the laboratory.

A new plan for teaching physics was outlined in a circular from the Department of Public Education. The teacher's role was limited to selecting topics for experiments and providing general guidelines, while students were given the freedom to determine all the details of a given experiment. The old system, in which the teacher lectured the class on the principles underlying a particular topic, explained in detail the rules to be followed and the mistakes to be avoided, while the student obediently followed his instructions and thereby relinquished all responsibility for conducting the experiment – this system was deemed impractical.

The Circular stated: “The role of the teacher is defined by the fact that he must guide and direct, stimulate interest, and offer new ideas; he must never be content with merely presenting ready-made conclusions. The Department wishes to emphasize once again that the new curricula being introduced must be based on intellectual discipline –this is their primary goal... The essence of the work lies in each student individually and independently investigating a specific laboratory task; as for the teacher’s presentation of the subject matter and demonstrations, these should be given secondary importance. The practice of forming groups of two students to conduct independent research should no longer be followed. The same task should be given simultaneously to all students in the class, although it may be presented to different students in different forms” [176].

Thus, starting in 1898, laboratory exercises became the foundation of the educational system. Classes were conducted in a lecture-style format, and assignments could be tailored to consider the abilities of individual students.

A distinctive feature of how physics was taught in England at that time, and how students studied it, was the mandatory keeping notes in notebooks. The Department attaches great importance to the conscientious and accurate keeping of these notes, but teachers are prohibited from dictating them. All observations must be recorded at the workplace, in the laboratory; writing drafts or on separate sheets of paper was prohibited. Along with the individual answer obtained for a given task, each student records in their notebook the conclusions drawn from the observations by the entire group working alongside them.

Influenced by the successes achieved as a result of secondary education reforms in America and England, and under pressure from public opinion, which demanded teaching that was not abstract but connected to real life and suitable for practical applications, France underwent a shift in both the methodology of physics instruction and the content of the curriculum. The 1902 law states:

The goal is not to turn our students into real physicists, but to familiarize them with the great laws of nature and to enable them to understand the phenomena occurring around them.

To achieve this goal, two approaches were proposed:

1. Bring students face-to-face with the phenomenon being studied; work together to find the best way to study it; together with them and under their guidance, invent an apparatus suitable for the task at hand; begin studying the phenomenon after examining it; determine the results obtained in accordance with the accuracy of the chosen method and the apparatus at hand; apply the results obtained.

2. Give students the opportunity to apply the method developed in this way during practical exercises.

Many teachers had experience using the first of these methods, but the second required creativity. Official instructions did not specify the content of practical exercises; they merely provided guidelines such as the following:

The teacher must prepare practical exercises with the same care as classroom assignments. They are granted the broadest possible discretion regarding the choice of exercises. At times, the teacher may limit themselves to having students make simple qualitative observations, but more often they will proceed with measurements, keeping in mind the degree of precision appropriate to standard experimental conditions.

The results of the reform, and particularly the conduct of practical work, were on display at the 1910 World's Fair in Brussels. In the French Education section, the lyceums exhibited laboratory equipment, the assignments themselves, and, most notably, numerous instruments made by teachers and students.

When students begin their projects, they start from scratch. Often, they not only design the setup but also make the tools themselves, learning in the process how to work with wood, metal, and glass. Of course, students do not spend time making tools for every single project. In general, the labs were well-equipped with the necessary tools, but each group had to complete several design projects of varying degrees of complexity during the classes themselves.

Professor François Dewalve describes the procedure for laboratory work as follows: "First, the tasks are presented to the students; then, to encourage them to experiment, the instructor asks them how they plan to set up the experiment and gradually guides them in the right direction. Then the students offer their comments and ask questions. Only after this do they begin the experiments, which last about 30–35 minutes. The remaining time is devoted to calculating the results obtained. Then the teacher again guides them and discusses the results with them. At home, in their free time, the student then describes the entire exercise in detail in a separate notebook, and the teacher reviews it from time to time" [176].

While in France educational reforms took place with government involvement, in Germany they were initiated by individual societies and associations.

One of the most active proponents of physics education reform in Germany, Professor Grimsel, director of the Hamburg Realschule, wrote: "The movement launched by the Hamburg Society for Natural Sciences in 1901 found expression in the so-called Hamburg Theses on the Reform of Natural Science Education, which were presented at the congress of German natural scientists and physicians in Breslau in 1904. A commission was formed there, tasked with refining certain aspects of the theses and developing a draft that would be acceptable to all. This commission submitted a report on its activities to the congress of natural scientists in Merano (1905). It summarized the requirements that modern natural science education must meet to serve the needs of human life" [177].

Regarding laboratory sessions, the report stated: "For modern educational purposes, it is not enough for a student to watch from a distance as experiments are conducted on the lab bench; even under the most favorable circumstances, this may lead to an insufficient understanding and a passive perception of what is taking place. Only when a student works independently to conduct at least the simplest experiments will they learn to discuss phenomena comprehensively and logically, observe critically, and act prudently" [177].

The resolutions of the congress of German natural scientists and physicians in Merano (1905) established the following principles for the curriculum:

Principle 1: When teaching physics, it should be viewed not as a mathematical science but as a branch of natural science;

Principle 2: Physics, as a subject of instruction, should be taught in such a way that it serves as an example of how knowledge is generally acquired in the field of experimental sciences;

Principle 3: For the physical education of students, systematically designed exercises in observation and experimentation, conducted by the students themselves, are necessary.

In 1910, the Saxon and Bavarian governments recognized the need to introduce mandatory physics laboratory classes in secondary schools.

Thus, beginning in the 1780s, there was a steady shift from older methods of teaching physics to new ones. This evolution was not completed until the early 20th century, creating the conditions for a transition to a new system, the main features of which include the following:

1) The goal of teaching physics in secondary school: to develop in students accurate and clear concepts of the most important phenomena and laws of elementary physics and to connect these concepts with the demands of daily life and the interests of modern technology.

2) The old, so-called lecture method is considered obsolete; it cannot be justified even by classroom demonstrations, which are given a secondary role. Independent student exercises in the physics laboratory, using simple apparatus – homemade where possible – are given a prominent place.

It is advisable to conduct laboratory work as a group, and ideally, all members of the group should work independently using identical equipment.

3) The instructional time allocated by the curriculum for physics should be distributed among classroom instruction, students' practical exercises in the laboratory, and their work on textbooks; furthermore, it is recommended that no more than half of the total instructional time be devoted to laboratory exercises.

4) During group laboratory work, it is advisable to differentiate tasks for individual students, considering that the subject of study is the same for all students.

5) When conducting laboratory work, the student assumes the role of a

"researcher," understanding this to mean the acquisition of new knowledge.

Thus, attention is drawn to the research-oriented nature of laboratory work.

6) The most common structure for classes involving group laboratory work was as follows: discussion of the objectives and plan of work; conducting the laboratory work; summarizing the results.

The concept of physics instruction in schools of the Russian Empire until the late 1890s can be described using the recollections of Professor G.G. De-Metz, which can be found in his book "General Methodology of Physics Instruction," one of the first domestic works on physics methodology.

G.G. De-Metz's recollections are since in 1878 he began studying physics as a sixth-grade student at the Richelieu Gymnasium in Odessa.

He writes that "although this gymnasium was considered exemplary and well-equipped, the students were not shown any physics experiments; and when we began to insist, we were taken to the physics lab twice, shown a few things, and that was the end of the experimental part of the instruction, leaving us to study everything else on our own from Malinin's textbook.

As far as I remember, the physics lab was crammed with numerous cabinets, and the cabinets were full of various instruments, but not a single experiment remains in my memory, because all instruction always took place in a regular classroom, standing at the blackboard with chalk in hand. Chalk replaced all the equipment and all the experiments; hence the "chalk era" of physics.

I had to finish high school in Mykolaiv, and it was much the same there: there seemed to be a decent physics lab with cabinets full of equipment, but they didn't show us any experiments – at least none that would have stuck in my memory as something systematic and interesting. And here, chalk was what saved the teacher from a difficult situation all the time" [176].

This situation in physics education persisted until the late 1890s, when voices of protest finally began to be heard against the status of physics as the primary natural science discipline in secondary schools. The first to speak out about this in the press were Soviet professors F.N. Shvedov, O.D. Khvolson, and M.O. Umov. F.N. Shvedov wrote in "Introduction to the Methodology of Physics", published in 1891 in Odessa: "It should be noted that there is no mention whatsoever of a physics curriculum in the strict sense of the word in secondary schools. The subject is mentioned in the "Rules and Curricula of Classical Gymnasiums". In addition to the curricula, we find there: "a curriculum for the Russian language and Church Slavonic"; "an explanatory note to the curriculum for ancient languages"; the same note "to the mathematics curriculum"; also "to the history curriculum"; and the same for the "geography curriculum." But for physics, there is only an "explanatory note to the physics curriculum". From this perspective, physics is equated with "drawing"; for it, too, there is no curriculum, only a program."

Professor M.O. Umov also acknowledged that the teaching of not only physics but all natural sciences in secondary school was unsatisfactory. This dissatisfaction, he said, stemmed from the fact that schools were not adapted to the needs of experimental teaching. Schools do little to cultivate such important elements of education and upbringing as the development of observation skills, the ability to handle facts, and exercises and operations involving facts.

At that time, there were no "physics classrooms" anywhere. Physics labs were completely unsuited for conducting experiments; they could not even accommodate the entire class of students.

The situation described regarding the status of physics among other disciplines in secondary school could not satisfy physics professors, above all. For in their university work, they had to deal with students who were not only poorly prepared but also completely indifferent to such an important and interesting branch of natural science. Therefore, in 1894, F.N. Shvedov wrote in the concluding paragraph of his "Introduction to the Methodology of Physics": "The above, I believe, demonstrates quite clearly that physics is currently not treated properly in secondary schools, and that this science does not meet the requirements of general methodology. It is necessary to carry out a fundamental reform of both the curriculum and the methods of its instruction".

F.N. Shvedov's voice fell on deaf ears among his peers, who were ill-prepared, and thus had no practical significance.

In 1898, Professor M.O. Umov began advocating for the need for reform as chairman of the "Commission on Measures to Improve the Teaching of Physics in Gymnasiums," which operated under the Moscow School District. In addition to M.O. Umov, this commission included such a researcher as P.M. Lebedev.

This commission did much to improve the teaching of physics.

While adhering to the 7-hour standard for the physics course, she did not expand the school curriculum but thoroughly revised it, placing the teaching of physics in an entirely new context. She required that every gymnasium or real school establish a separate physics classroom and equip physics labs with the necessary instruments to meet the standard. To this end, she compiled a list of instruments and equipment for a standard physics laboratory. At the same time, she issued a resolution to train physics teachers and maintain their knowledge at the level required for teaching this subject in the model physics laboratories established in each district. The commission also established specific guidelines for the study of physics in secondary school, namely:

1. Students must acquire such knowledge about nature that, on the one hand, is necessary for an educated person, and on the other hand, would enable them to independently expand their knowledge after leaving school. At the same time, students must develop the ability to apply scientific knowledge to explain everyday phenomena.

2. Students must be open to changing their beliefs, because true knowledge consists of carefully examined facts and the laws that directly follow them. Students should be interested not only in broad scientific generalizations but also in the laws that govern specific phenomena, because it is only through the combination of such phenomena that all changes in nature occur.

Laboratory classes have a long history in Ukraine. They were first explicitly proposed and promoted as a method of school instruction at a conference of physics and chemistry teachers in late December 1899 in Moscow. Following a report by V.F. Davydovsky on practical physics classes, a unanimous decision was made to recognize the necessity of practical physics classes.

Prior to this, physics teachers at several schools had, on their own initiative, begun conducting a series of laboratory experiments with interested students. The accumulated experience, presented in the form of reports, was brought before the congress and met with great sympathy by the participants, as it addressed a growing need in teaching. It served as a certain impetus for the development, expansion, and more proper organization of laboratory work. But these first steps were still very tentative. The congress resolution spoke only of the desirability of introducing practical exercises in physics.

An illustration of the fact that the resolution was not an expression of universal recognition of practical physics classes can be found in one of the resolutions of the subcommittee on physics education, drafted in 1900: "Resolution 2. The organization of practical classes for students should be recognized as desirable where possible, but they should not be considered mandatory for students. The subjects of these classes may primarily include personal and direct familiarization with physical phenomena; simple measurements and verification of certain laws. It is desirable that the teacher receive special remuneration for conducting these classes" [178].

It was not until 1911, at the 2nd Mendeleev Congress, that physics teachers began to speak with greater insistence and greater rigor about the implementation of laboratory work.

At the first All-Russian Congress of Teachers of Physics, Chemistry, and Astronomy, a resolution was adopted making laboratory work mandatory.

During preparations for the congress, which took place in 1913 in Petrograd, key issues were identified that were the focus of the questionnaire and appeals to various organizations, requesting that they express their views.

The "collective" responses and opinions received on the main issues greatly facilitated the work of the congress sessions. They were received from the Moscow Society for the Study and Dissemination of Physical Sciences, from the Physics and Mathematics Committee of the Pedagogical Society at Kazan University, from the Kyiv and Odesa branches of the Executive Committee, and from the Natural Sciences Section of the Riga Pedagogical Society.

The results of the congress were reflected in its resolutions, particularly regarding practical classes:

Practical physics classes in secondary school are mandatory for educational institutions and teachers; as a teaching method, they are conducted during the hours designated for physics lessons, with the teacher having complete freedom in choosing the method for conducting practical classes.

The construction of homemade devices should not be the subject of practical classes but may be encouraged during extracurricular time.

From the perspective of the current state of educational equipment production in Ukraine, the congress resolution “On the Procurement of Equipment” is of particular interest:

1. Teachers must be given the opportunity to gain an accurate understanding of the quality and cost of Russian and foreign-made equipment and instruments, as well as where they can be purchased.

2. To achieve this goal, it seems most appropriate to hold regular exhibitions of Russian and foreign-made devices. At these exhibitions, laboratories should be organized where teachers could test the devices and become more familiar with them.

3. The current dependence of Russian schools on foreign manufacturers of educational devices and instruments creates several difficulties. Efforts must be made to eliminate them; however, this must be done with the utmost caution and a thorough understanding of the true situation.

4. Russian schools must be protected at all costs from having to purchase, at high prices from Russian trading firms, equipment and instruments from foreign – and sometimes second-rate – manufacturers that are of very poor quality, causing them to be short-lived or even completely unusable.

In 1915, a Commission of the Ministry of Public Education noted that practical exercises should constitute an integral part of the physics curriculum, as essential as lectures, rather than merely an adjunct to lectures, which, in the eyes of both teachers and students, is of only secondary importance; furthermore, they should, whenever possible, be integrated throughout the entire course of instruction. A particularly close connection between practical exercises and lectures should exist at the elementary level.

At the same time, from 1900 until the revolution, the following questions were debated in journal articles, at society meetings, and at conferences: whether laboratory work should be mandatory in schools or not; if it were mandatory in schools, whether it should be mandatory for all students; whether experiments should be conducted as group activities or individually, be primarily qualitative in nature, precede the study of a phenomenon (be heuristic in nature) or follow the study of a phenomenon (be verification-based), and be conducted primarily by the students themselves or using ready-made apparatus set up in the laboratory.

As will be seen in the second chapter, these questions will remain relevant in the further development of physics education.

Thus, prior to the revolution, the conditions had been created for the practical use of laboratory work in the teaching of physics in secondary schools.

The outcome of various meetings and conferences on physics instruction in secondary schools in Russia can be seen in the consideration of laboratory work as a teaching method. Specifically, this refers to whole-class laboratory work.

For twenty years prior to the October Revolution (1917–1932), the efforts of individuals, scientists, and pedagogical societies, as well as conferences, continued unabated in the struggle to improve teaching, and to find better teaching methods, to increase the scientific rigor and practical relevance of curricula and programs. Even despite the disruption of transportation and food supplies, on June 5 - 9, 1917, following the coup d’état, a conference was held, attended by all those who, through their work over many years, had contributed to the development and success of natural science education in Russia. In the physics section, the following were deemed necessary: 1) dividing the course into two levels; 2) structuring the first level around practical exercises; 3) structuring the second level around classroom experiments conducted by the instructor and the simultaneous conduct of practical exercises.

The Decree on the Unified Labor School and the corresponding directive of 1918 dismantled the old education system and closed existing schools without replacing them with anything of equivalent value.

The period from 1918 to 1931 was characterized in a Resolution of the Central Committee of the All-Union Communist Party (Bolsheviks), which was adopted in 1931. It noted that it was necessary to address the struggle against frivolous methodological adventurism and the mass-scale imposition of methods that had not been previously tested in practice.

However, during this period, works on physics teaching methodology by M.O. Kashin, G.G. De-Metz, V.V. Lermontov, and others were published.

In the 1920s, despite the thesis put forward by some researchers regarding the necessity of using various teaching methods, there was a trend toward the universalization of the research method. This was accompanied by a disregard for the role of the textbook in the educational process, a rejection of verbal teaching methods – which were considered dogmatic – and a denial of the teacher's guiding role.

This enthusiasm for the research method also shaped the structure of classes, as described by G.G. De-Metz: "In the past, we were accustomed to a strict school routine, where the entire school day was divided into hours and minutes, where lessons followed one after another at the sound of the bell, and where the duration of each class period was always the same – about an hour. And when the students of a given class were engaged in a single task, under the constant supervision of the teacher. Now, from this perspective, a huge shift has taken place: in many schools, classrooms have disappeared, having been replaced by laboratories; although the school day is still divided into hours, students, by their own choice, go to the laboratory that now interests and attracts them; there are no longer daily lectures or quizzes, as assignments for each subject are completed over more or less extended periods, for example, from two weeks to a month; the old-fashioned method of learning, where students listened to what the teacher said, is being replaced by more or less well-structured self-study; even the assessment of academic performance, which used to cause students so much anxiety, is now conducted through tests in many schools; moreover, the testing system has now been so refined and simplified that students can test themselves" [176].

G.G. De-Metz notes a positive aspect of this approach to organizing classes: "The material that students work through is the same for all students, but it requires different amounts of time and effort for each of them to master it; some do so slowly, while others do so quickly" [176]. This is considered in the described teaching methodology, because each student spends as much time as they need to master any subject. And they begin their work on their own initiative when they feel they are ready for it.

The described teaching methodology constitutes the essence of the Dalton Plan. This system of instruction was created by Helen Parkhurst, who was inspired by the educational ideas of the Italian physician Maria Montessori and realized her vision in 1920 at a normal school in the town of Dalton, Massachusetts, in the United States.

It was during this period that a distinctive feature of physics textbooks emerged, one that would become a tradition and was linked to the inclusion in textbooks of laboratory instructions that varied in content. It was precisely in 1925, at the height of the Dalton Plan craze, that demands to develop a type of textbook that would most effectively engage students to reach their peak.

This type was developed in the form of a "Workbook" and found its first implementation in the "Physics Workbook" for workers' faculties, compiled by a team of authors under the editorship of I.I. Sokolov, which was published in 1926.

The workbook was intended to fulfill two main tasks: 1) to accompany the student through all aspects of their work, serving as their sole textbook; 2) to place the student in the position of a person who independently acquires knowledge, if not through research, then at least through heuristic methods.

The first edition was structured as follows: a coherent flow of the book's text; a manageable number of laboratory exercises; follow-up exercises; and problems and review questions. All these parts were intended to be integrated and arranged in such a way as to guide the students step by step in their work. This first task was satisfactorily resolved. But the second task – to provide all the necessary material for study in a systematic order while preserving the student's independence in acquiring knowledge – posed insurmountable difficulties. In the first "Workbook" edited by I.I. Sokolov, this task was addressed by presenting most laboratory exercises in a heuristic manner; students themselves derived a law from the work that was not formulated in advance in the book, and in some cases this conclusion was not further justified but was subsequently referenced.

In the 1927 "Physics Workbook," just as in the 1930 "New Physics Workbook," Bachynsky, guiding students to a conclusion through well-designed experiments, presents a framed, nearly complete conclusion, leaving out only a few words that the students themselves must fill in.

In subsequent textbooks, conclusions are not always provided. In the 1930 "Physics Workbook," E.M. Goryachkin provides 18 laboratory exercises of a qualitative and, in part, quantitative nature; in most cases, primarily following qualitative experiments, the next paragraph describes additional experiments on which a conclusion can be based, and the conclusion itself is drawn, but in some works, neither conclusions nor further analysis are provided. Thus, students must limit themselves to what they discover from the experiments on their own. In other cases, the author leaves space in the book after the laboratory exercises, suggesting that students transfer either the numerical data of the experiment or the conclusions themselves from their workbook into the book.

The books cited above represent extreme forms of attempts to solve the primary methodological task set for the "Workbook." However, these books had significant shortcomings. The omission of the formulation of the law from the book, while ensuring students' independence in discovering the physical law, does not guarantee the correctness of their conclusion and requires supplementing the workbook with a work notebook containing the conclusions from the experiments.

Limiting independent research to individual words that must be inserted into pre-formulated sentences – while increasing the likelihood of a correct conclusion – reduces students' active engagement in arriving at that conclusion. Inserting individual words, or an entire conclusion, eliminated the need for a workbook supplement to the book, but renders the book itself obsolete after a year, as it ceases to be, due to the inserted material, a tool for engaging students. Entries in the book cause unacceptable defacement of it.

Immediately after the publication of the "Physics Workbook" for labor schools, edited by I.I. Sokolov, loud protests began to be heard from the student community, claiming that the book could not be used in the following cases: when the educational institution lacks the equipment for which the book is designed; when the book has to be used for review; when students who have missed a class for some reason are forced to use the book.

These compelling complaints led to a change in the presentation style, and, starting with the second edition of the book for workers' faculties, the inclusion of experimental justification and the derivation of the law following laboratory work. The heuristic nature of the work was preserved; the students could discover the law on their own, but in return they were given an interesting opportunity to verify their conclusion and repeat the law at any time, regardless of the laboratory work. This nature of the book for workers' faculties persisted until the 9th edition in 1932, in which a crisis of the "Workbook" type had come to a head. This was linked to the need to introduce technical material, which led to an undesirable increase in the book's volume.

Thus, one of the directions in the organization of students' educational activities is the organization of heuristic laboratory work, combining it with work using the "Workbook," which served as a means of guiding students' actions.

At the same time, research is being conducted on the methodology for organizing laboratory sessions as a component of the overall system of physics lessons.

Let us consider the methodology for organizing group work described in the book "Methods of Physics" by M.V. Kashin, published in 1922.

At the beginning of the school year, the class should be divided into groups of two students. Before starting the activity, the teacher explains the purpose of the exercise to the entire class, and the students write down this explanation in their notebooks. The following sequence is recommended:

1. The research task itself is explained.

2. The necessary formulas are written on the board, and a diagram of the setup is drawn.

3. The experimental process is divided into sequential stages.

4. Instructions are given on how to use the equipment.

5. A student is asked to list what they need for the upcoming work; everything

listed is written on the board.

6. The necessary materials are distributed to each group.

After this, the work begins. The teacher's role at this stage is limited to checking that students follow the instructions and observing the progress of the work.

Once all students have finished their work, their results should be written on the board; either immediately or during the next class, the process, any difficulties encountered, the results obtained, and any mistakes made are discussed.

At home, students write a report. It should include: 1) a statement of the research problem; 2) a description of the apparatus and setup (with diagrams and drawings); 3) a description of the experimental process and observations; 4) the results obtained; 5) analysis of the results, i.e.: a) calculation of the average from the observations of all groups; 6) error estimation (determination of the relative error and its expression as a percentage).

Work at the first and second levels should differ from one another in nature and objectives.

At the first level, in line with general trends, practical exercises are aimed primarily at familiarizing students with phenomena; subsequently, they gradually introduce students to measurement practices; accordingly, many of these exercises are qualitative in nature.

Assignments in the second stage are primarily research-oriented; they then focus on establishing relationships between the quantities that characterize a phenomenon, as well as familiarizing students with certain technical applications [178].

The Resolutions of the Central Executive Committee of the All-Union Communist Party (Bolsheviks) "On Primary and Secondary Schools" of September 5, 1931, proposed that teaching in schools be conducted according to fixed curricula, programs, and a fixed schedule; the programs were to ensure a precisely defined scope of systematic knowledge in each academic subject.

The physics curricula for secondary schools from 1932, 1933, 1935, 1938, and 1940 reflect a gradual improvement in the content of the school physics course and in teaching methods. During this period, the first standard physics textbooks were created, authored by: G.I. Faleev and O.V. Pyoryshkin (1933–1948); I.I. Sokolov (1938–1954).

Methodological works such as "Laboratory Classes in Physics in Secondary School" by P.O. Znamensky (1936, 1940, 1955) and "Organization of Physics Laboratory Work in Secondary School" by V.N. Bakushinsky (1948–1949) had a significant impact on the improvement of physics instruction in Soviet schools.

The major works on physics methodology by P.O. Znamensky, I.I. Sokolov, and E.N. Goryachkin examine the methodology for organizing and conducting physics laboratory classes. Overall, the views of these methodologists on this type of educational activity coincide.

Let's examine the structure of this type of class.

In most cases, a lab session takes up an entire hour-long class period. Some quantitative tasks require two consecutive hours to complete. Some qualitative tasks can be completed in a few minutes; these should be combined with a lecture on new material and a demonstration by the instructor.

The main methodological requirement for designing a laboratory assignment, regardless of its nature, is an organic connection to the material being taught. A laboratory assignment is assigned when, while presenting new material, the teacher has led the students to the question whose answer they must obtain through independent laboratory work, or when the presentation of the topic on which the students are to conduct verification experiments has been completed. A time gap between the laboratory work and the material being studied deprives the laboratory work of its character as a teaching method for the instructor and a learning method for the students.

The second essential requirement is a clear objective for the laboratory work. Students must have a clear understanding of what they are studying through a particular activity.

Both before a demonstration and before a laboratory activity, the teacher presents the students with a problem that they must solve on their own, but – of course – with the teacher's assistance.

Therefore, the laboratory work lesson begins with posing a question that follows from the previous explanation. To foster a conscious approach among students toward performing the work, the teacher discusses with them the methods and tools that can be used to find the answer to the question posed, encouraging them to plan independently, at least in part, wherever and whenever possible. It is also advisable to outline, together with the students, the main parts of the work plan and a scheme for recording numerical results, which in this case is written on the board.

This introduction should take about 10 minutes during a one-hour class.

After the instructor's briefing, students should read the work guide from beginning to end and only then begin assembling the setup using the individual components provided to them.

Next comes the time for students to work independently.

During this time, the teacher observes the progress of the groups, offering brief advice or leading questions as needed, and pays particular attention to groups that are struggling with the task.

Students take measurements, record the numbers in a table, process the obtained numbers in their notebooks in the order specified by the teacher, find the answer to the questions posed, and report it to the teacher. By this time, the blackboard should be divided into as many columns as there are working groups, and each group records the result they found in the corresponding column.

After all columns have been filled in, or as the lesson nears its end, the teacher checks the work of groups that have not yet finished a few minutes before the end of class, drawing the entire class's attention to the columns that have been filled in completely or partially, and leads a group discussion of the experimental results. If a law is derived, the teacher provides the final formulation of the law.

The activity concludes with the preparation of a report, which in some cases may be completed during the same lesson, but in most cases must be prepared as homework.

Although students work in groups, reports are written individually. This compels each student, regardless of which part of the work they performed, to think through the entire process from start to finish.

The report includes the following sections: the date and number of the assignment, the topic of the assignment, a diagram of the experimental setup, a table with numerical data, calculations, a very brief description of the experimental plan, and a conclusion.

If we compare the general plan for conducting a laboratory lesson described here with the one described by N.V. Kashin, we can see similarities in certain stages.

In the mid-1950s, following the 20th Congress of the Communist Party of the Soviet Union, a period began characterized by teachers being granted relative freedom in organizing the educational process. In the field of education, the issue of "comprehensive development of students' activity and independence in their academic work" became a pressing concern.

This led to a discussion regarding the organization and conduct of physics laboratory work in secondary school.

The previous stage of the educational process in secondary school can be described in the words of M.N. Skatkin: "At the previous stage of the educational process, didactics required that the teacher systematically present and explain all the topics covered by the curriculum. Only after such an explanation were teachers permitted to assign students tasks for independent work, the purpose of which was to reinforce the knowledge presented in a ready-made form and to practice skills" [178].

This statement refers to the period from the late 1930s to the mid-1950s. As can be seen, this organization of classroom instruction did not align with what had been observed in all previous stages of general education development, both abroad and in the Russian Empire, namely the emphasis on organizing students' exploratory activities during physics lessons.

If we turn to works on physics teaching methodology, we can find the following key principles regarding the organization of laboratory sessions.

P.O. Znamensky's statement is indisputable: "…every laboratory experiment conducted by students will yield positive and valuable results only when students fully understand the purpose of the upcoming work and the steps they must take to achieve the set goal. Students must clearly understand how the work assigned to them relates to previously studied material or what objective it serves for further progress." And, at the same time, the conclusion is drawn: "Therefore, when assigning independent work to students, the teacher must conduct a preliminary discussion with them" [179].

This conclusion, together with his other statement: "…the introductory and concluding remarks may be omitted or kept very brief as the lesson progresses; the first – because everything necessary for the work has already been covered in the preliminary presentation of the material; the second – if the work was simple and its progress showed that the students understood it" [179], initially led to the traditional conduct of laboratory work and then to a complete divergence on this issue. The formulaic nature of conducting laboratory work lay in the fact that teachers considered the presence of three stages in the lesson to be mandatory:

a) the teacher's preparation of students for the work: the teacher introduces the topic of the work, its purpose, demonstrates the equipment, and, if necessary, how to use it, and so on;

b) students conducting the experiment;

c) processing and utilizing the results.

This, of course, did not and does not contradict the methodological requirements for conducting laboratory work; however, having become a rigid form of instruction, it has led to a decline in students' independence and to formalism in their work.

Starting in the late 1950s, to revitalize the educational process and foster students' independence in their work, some teachers rejected both written and oral instructions, while others, on the contrary, considered them an essential element of the laboratory work lesson.

For example, in his publications, S.S. Klos [180] argued that a higher level of independence is required when performing tasks without explanations or instruction cards, when the teacher merely formulates the task and specifies the necessary equipment. A similar point of view is expressed by Chepurenko V.G., Nizhnik V.G., Haiduchok G.M. [181], and other authors. On the other hand, active and conscious performance of laboratory work is ensured only if the goal and the entire plan for its execution are discussed in advance in class. This view was held by M.S. Shulga [182] and several other authors.

This dual approach to conducting laboratory work can also be found later.

When considering the conduct of laboratory work without prior instruction, it is necessary to determine how to prepare students to conduct experiments independently. There has been no consensus on this issue either. For example, T.V. Gulyayeva, O.V. Sergeyev [183], and others believe that such laboratory work is particularly successful if experimental problems were solved in previous lessons and students have thoroughly mastered the theoretical material. Galatyuk Y.M., Tishchuk V.I., and Andrukhov D.Y. consider the development of independence in terms of the laboratory work itself: “In the seventh grade, we conducted the first three experiments with careful instruction… subsequently, elements of independence were introduced” [184].

At that time, “frontal experiments” by students – frontal experiments and observations – became widespread. Justifying the need for their introduction, O.I. Bugayov wrote that demonstration experiments have the significant drawback that they are perceived by individual senses, and thus the role of the primary sensory system in perceiving reality is weakened. The inclusion of a frontal experiment or observation in a lesson eliminates this drawback and simultaneously serves as a method for increasing students’ independence [179].

Some authors view the “frontal experiment” as supplementary short-term laboratory work, while others see it as a new type of educational physics experiment.

In this case, no resolution to these disagreements was provided.

The path to resolving these differences in views on the organization of physics laboratory work in secondary school was outlined by V.I. Kalenyk in 1963. The essence of these proposals was as follows: it is necessary to consider the methodology for conducting laboratory work not in general, as is done in all physics methodology manuals, and not individual laboratory exercises, but rather their groups, classifying these exercises according to their content. Such groups include laboratory experiments: 1) involving direct measurement of a physical quantity; 2) involving indirect measurement of a physical quantity; 3) involving the study of physical phenomena; 4) involving the study of technical devices; 5) involving the study of the laws of physics.

In this case, all authors are correct, but their views apply only to the methodology for conducting specific groups of laboratory work.

Later, this idea was implemented in a methodology for organizing small-group laboratory work, which was based for the first time on a general plan of activities during a physics experiment designed to assess the experimental skills of high school graduates. Based on the plan of activities proposed by V.I. Kalenyk for conducting various types of physics experiments, it became possible to answer the question: Are the frontal experiments and observations proposed in the 1960s equivalent to frontal laboratory work?

Given that this methodology for conducting laboratory work has been included in a textbook for students [185], let us consider, for example, two groups of experiments that precisely illustrate the resolution of the described contradiction.

A generalized plan of activities during the conduct of any educational physics experiment.

1. Formulating and understanding the objectives of the experiment.

a) Determine which physical phenomenon, process, or property of objects needs to be studied;

b) Understand what needs to be determined through experiments: provide a general description of the phenomenon; graphically represent the process; establish relationships between physical quantities, etc.

2. Planning the experiment.

a) Select the object of study.

b) Determine the experimental methodology: draw a schematic diagram of the experimental setup, list the necessary equipment and materials, and develop a plan of action.

3. Carrying out the plan.

a) Select the necessary equipment and determine its main parameters.

b) Assemble the experimental setup.

c) Conduct observations and measurements.

d) Record the results obtained.

4. Analysis of the results obtained.

a) Process the data obtained in accordance with the stated objective.

b) Draw conclusions.

c) Prepare a report.

This general outline is typical of the collaborative work between a teacher and students when conducting any educational physics experiment. At the same time, the content of each stage depends on many factors: the type of experiment; the specific steps involved; the experiment's place in the educational process as it relates to the study of a particular curriculum topic; the students' existing skills; and so on.

The content of the individual stages of this plan depends on the objectives that this type of educational experiment aims to achieve, particularly specific groups of laboratory exercises.

Laboratory exercises on the direct measurement of physical quantities.

Objective: To help students develop the ability to use measuring instruments.

Components of the skill of using measuring instruments: identifying the instrument; determining the instrument's characteristics based on its scale; performing a series of operations to prepare the instrument for measurement and conducting the measurements themselves; recording and evaluating the measurement results.

Main stages of developing practical skills: 1) designing a procedure that constitutes the content of this skill; 2) demonstrating a model of this procedure; 3) having students perform the first sets of actions based on the provided model; 4) applying this procedure to solve a specific problem.

Types of educational experiments: demonstration experiment (Stage 2); laboratory experiment – "classroom experiment" (Stage 3); laboratory work (Stage 4).

Task for the laboratory work: by comparing the measurement results, draw a conclusion about the characteristics of the object of study.

The purpose of the laboratory work is determined by the fact that the ability to use a measuring instrument is part of the content of the corresponding physical quantity: "this physical quantity is measured by the instrument…".

The general procedure for studying this physical quantity – and developing the skills to measure it – is as follows:

1. The essential characteristics of the physical quantity are introduced: name, symbol, definition, formula, and unit of measurement.

2. A cognitive problem is solved: how to measure this physical quantity?

a) the instrument is studied;

b) the rules for using the instrument are demonstrated;

c) a demonstration experiment is conducted – students replicate the sequence of actions based on the given example.

3. A laboratory experiment is performed.

As can be seen, in this case no instruction is required, because the method of activity that determines the content – the ability to use the instrument – must be mastered by the students during the second stage.

The assignment for this lab requires planning and conducting a small-scale study.

If, during the first lab assignment in this group, a sample report is provided that effectively outlines the sequence of steps for the student, it is possible to achieve maximum student independence when they complete subsequent assignments in this group.

This methodology for conducting lab work aligns with the views of the scholars and other physics teachers and instructional specialists.

Laboratory experiments on the study of physical phenomena.

Objective: To describe the subject of study – a physical phenomenon or its underlying pattern.

To study any phenomenon, it is necessary to identify its characteristics, by which the phenomenon can be distinguished from others. This can be done as follows: 1) demonstrate the phenomenon and collectively identify its external characteristics; 2) give students the opportunity to identify the phenomenon's external characteristics on their own, that is, to perform the laboratory work outlined in the curriculum.

If the external characteristics of the phenomenon are demonstrated by the teacher, then repeated independent observation of them has no value. The student already knows the result of the observation. Therefore, it is advisable to conduct such laboratory work before studying the physical phenomenon. In such work, non-standard equipment is usually used, which is needed only for this task.

Before conducting this laboratory experiment, the teacher must provide detailed instructions: explanations, and, if necessary, a demonstration of what needs to be done and how. During the experiment, the teacher should assist students in identifying the characteristics of the phenomenon.

As can be seen, the methodology for conducting this group of laboratory experiments aligns with the views of both V.G. Chepurenko, V.G. Nizhnik, and G.M. Haiduchok [181], as well as O.G. Galitsky, M.V. Gadetsky, V.G. Kulish [186], and other physics teachers and methodologists.

Thus, the development of specific methodologies for organizing and conducting laboratory work sessions resolves the contradictions in the views of physics teachers and methodologists regarding this type of educational activity and fully aligns with the general trend in the development of the educational process – the intellectualization of students' learning activities.

However, this methodology for organizing and conducting physics laboratory work has not gained widespread acceptance for the following reasons: 1) the fact that most physics teaching guides and textbooks focus on the traditional approach to organizing laboratory work, which took shape in the 1930s and 1940s; 2) the lack of publications on the proposed methodology in books that physics teachers – not only in the Sumy region – could consult; 3) opposition from a significant portion of school administrations, since this methodology does not fit into existing frameworks and, moreover, lacks approval from the Ministry of Education and Science of Ukraine.

After Ukraine became an independent state, there arose a need to create domestic physics textbooks for general education schools. Naturally, the introduction of new curricula and new textbooks requires the creation of methodological guides that would explore the most effective ways to organize the educational process.

In the physics textbooks used in schools in the Soviet Union, written instructions for conducting laboratory experiments were typically placed at the end of the textbooks. These instructions consisted of a list of equipment, the objective, and a brief description of the procedure. The content and placement of such instructions have been preserved in Ukrainian physics textbooks for grades 9 - 11, authored by S.U. Goncharenko [187].

This placement of laboratory work instructions allowed the teacher, considering the specific composition of the class, to decide how to use the instructions: to completely disregard them; to offer them to students who experience significant difficulties in studying physics; or to conduct laboratory work before or after studying the relevant theoretical material. The methodology for conducting laboratory work, of course, depended on the teacher's professional level and their understanding of the specific requirements for the educational process at this stage of school education development.

The textbooks "Physics. Astronomy" for grades 7 - 8, authored by O.I. Bugayov, M.T. Martynyuk, and V.V. Smolyanets [188], and later the "Physics" textbooks for grades 7 - 8, authored by E.V. Korshak, O.I. Lyashenko, and V.F. Savchenko [189], had one key difference from Soviet textbooks: instructions for laboratory work were included in the textbooks following the presentation of the relevant theoretical material. The nature of the instructions also changed. They were structured as had previously been done for physics laboratory work in schools and universities. Their content consisted of the objective, a list of equipment needed for the experiment, a summary of theoretical information, a more or less detailed description of the procedure; and tables for recording measurement results and calculations.

Thus, the textbooks guide teachers toward organizing laboratory work in a manner that was typical until the mid-1950s: a uniform approach to assignments, regardless of their purpose or content; and a lack of heuristic or exploratory elements. The purpose of the theoretical part of the instructions is unclear, as its inclusion could imply the following methods of use: 1) the teacher explains part of the content of the relevant component of the physics course to the students; 2) students study the theoretical part of the instructions on their own and then perform the experiment. Regardless of the ways of approaching the theoretical part of the instructions, the students cannot help but use the description of the procedure because they have already begun working with these instructions.

A positive feature of the theoretical section is that some instructions explain the conditions for conducting experiments. However, this is particularly important for complex tasks – those in physics labs. When it comes to lab work for grades 7 - 8, these experimental details can be covered during demonstrations.

Thus, even with the current content and layout of the laboratory work instructions in physics textbooks for grades 7–8, teachers can take a creative approach to using them.

But the fact is that various commercial publishers have flooded schools with "Workbooks" containing instructions for lab work identical to those in the textbooks. The student must enter the corresponding numbers into the workbook's table and write a conclusion.

This is not "help for the student", but a means of de-intellectualizing their learning activities.

Such "Physics Workbooks" have nothing in common with the "Workbooks" created in the 1920s. The latter were intended to organize students' exploratory cognitive activities.

The development of methods for organizing and conducting physics laboratory experiments in the works of Ukrainian physics educators proceeds along two main lines: the search for new laboratory experiments and the refinement of existing ones; and the search for ways to further improve the effectiveness of physics lessons that utilize whole-class laboratory experiments.

Let us examine the content of those works by educators that pertain to the second direction in their research.

Most of the work by these educators is devoted to developing students' creative activity and independence during laboratory work.

In this regard, T.V. Gulyayeva and O.V. Sergeyev [183] revisit the methods of conducting laboratory work, classifying them as reproductive, algorithmic, and creative.

In the non-productive method, the teacher explains and demonstrates all aspects of the work; in the algorithmic method, the work is carried out according to written instructions.

The activities of the instructor and students in the creative method of conducting laboratory work are presented in Table 1.

Table 1.

Activities of the teacher and students

Teaching Activities	**Student Activities**
1. Creates an environment conducive to creative exploration. 2. Assigns tasks that involve independently acquiring new knowledge, engaging in active and productive activities, and applying knowledge to non-standard situations. 3. The teacher guides students' active engagement and teaches them how to acquire new knowledge.	1. Actively engage in creative exploration. 2. Independently study literature. 3. Complete assignments. 4. Propose their own methods for conducting laboratory experiments.

Galatyuk Y.M., Voinovich I.S., and Ostapchuk M.V. [190] propose the following definition of creative laboratory work: creative laboratory work is a type of educational experiment conducted in a school laboratory that requires students to independently complete all or part of the stages of the creative cognitive process.

The performance of creative laboratory work is problem-based. It is usually based on a creative experimental task.

The cycle of creative cognition: generalization of facts → theoretical justification → experimental verification.

A task is considered creative for students if, while solving it, they must specify the research problem and develop an experimental model based on the analysis and application of their knowledge; the experiment is then carried out, and the results are evaluated.

The study conducted by the authors shows that the stage of developing the experimental model is particularly problematic: deriving the working formula, selecting equipment, and drawing up a plan for conducting the experiment.

Y.M. Galatyuk [191] examines the organization of laboratory work. The stages of laboratory work, apart from the final one (the experiment itself), can be carried out by students during a previous lesson or as homework.

Laboratory work can be organized by students as the final stage in the structure of their creative activity, the problem-based component of which is a creative experimental task, the process of which consists of two stages: modeling the experiment and the practical implementation of the model. The first stage is preparatory and involves creatively solving the problem “How to do it?” according to the following sequence: guess – idea – experimental model.

The second stage consists of laboratory work in the form in which it is traditionally practiced and presented in textbooks.

The first stage can be carried out by students outside of class, for example, while doing homework. In this case, the teacher should guide the students’ research. Guidance of learning activities in this case should be indirect. Its task is to inspire intuitive guesses during the creative process (“inspiration,” in translation, means inspiration, suggestion, or external motivation).

One of the heuristic techniques that allows for initiating students’ search in a predetermined direction is solving auxiliary calculation problems.

Other types of tasks for laboratory work are also proposed.

Lutsyuk T.V. [192] suggests creating sets of tasks based on the laboratory work instructions, supplementing, elaborating on, and updating them. It is sometimes helpful to include practical tasks that would increase students’ engagement and intellectual curiosity. Detailing these instructions allows for breaking down complex questions into simpler ones, accompanied by helpful guidelines aimed at mastering the core content. Updating is achieved by highlighting the main point in the experiment and presenting it as a question or problem. Questions and instructions should encourage students to perform various mental operations: analysis and synthesis, comparison, analogy, generalization, classification, and proof.

Vovkotrub V.B. and Vovkotrub V.P. [193] suggest that at the beginning of the lesson, each student be given a card with a task: within 5 - 10 minutes, theoretically determine a specific physical quantity, or verify the accuracy of a theory, etc. Six to seven options are selected so that no more than two students perform the same task.

Once this task is complete, the teacher collects the students' work and worksheets, then redistributes the worksheets with different options. Now each student must experimentally obtain the result specified in the task on their worksheet.

The final part of the lesson is a summary. An analysis of the quality of the theoretical and practical results obtained is conducted, and one or two grades are assigned for each stage of the work.

Myslinchuk V.O. and Tyshchuk V.I. [194] proceed from the premise that after studying a substantial amount of theoretical material, some form of assessment (a colloquium) is expected, and after studying specific laws and regularities, independent or test assignments are required. Therefore, it is entirely logical to plan and implement a specific form of assessment after completing the main stages of developing students' experimental skills. This form of assessment should take the form of some laboratory work. Moreover, this problem can be addressed in two ways.

First, it is necessary to revise traditional methods of assessing classroom laboratory work, shifting the focus from evaluating only the report to documenting all types of independent student activity during the assignment.

Second, new, specially designed assignments should be conducted to assess the development of specific skills – these are known as assessment laboratory assignments. The primary objective of conducting classroom assessment exercises, in addition to verifying mastery of theoretical material, is to determine the level of development of students' experimental, measurement, practical, and design skills and abilities.

The most appropriate methods for conducting these experiments, which fully preserve all control functions, are research-based. The experiment instructions must include the topic and objective, and the list of equipment should specify only those materials that are the subject of investigation in this experiment. The student independently selects the necessary measuring and other instruments and materials from those available in the physics lab's inventory. The instructions for performing the work are general and do not specify a particular action but rather indicate only the general nature of the activity.

Kryskov A.A. and Kryskov D.A. [195], analyzing the content and scope of laboratory work assignments in general education schools, note that they are, as a rule, simplified, do not require significant time investment, and the processing and presentation of results boil down to filling out the tables provided in the manuals. Thus, time is not used effectively in laboratory classes, and there is nothing to occupy gifted students.

Two types of additional tasks are proposed: some help students gain a deeper understanding of the laboratory work, while others require creative solutions (modifying measurement methods, improving accuracy, etc.). The first type of task is assigned to students in advance as part of their preparation for class. The second type of tasks is assigned either before the work begins or while the experiment.

While the works of the methodologists discussed describe new variations of well-known approaches to organizing laboratory work, the article by Sobko O.I. [196] is devoted to the use of personal computers and represents a novelty in physics methodology. One type of experimental-research task involves investigating a physical law or a consequence of it.

A logical flowchart for completing this task:

Observation of phenomena, gathering of facts → analysis of the facts obtained → identification of cause-and-effect relationships.

While performing the task, students, drawing on some empirical knowledge and their own life experience, select a set of facts through independent observations and based on their analysis and comparison, draw generalizations.

Such tasks can be assigned to students during physics lab work, using personal computers as experimental setups.

Depending on the didactic goals of instruction, computer-based modeling of a physical phenomenon can yield two types of models: the actual model of the physical phenomenon and a pseudo-model.

Pseudo-modeling is the reproduction of a phenomenon on a computer screen, a process that is purely deterministic. In this case, the “new information” is known and is either partially or fully embedded in the program.

Pseudo-models can be used to demonstrate physical phenomena and, in some cases, as a "laboratory setup." The information obtained because of working with a pseudo-program is new to the student.

It is recommended that students be given various tasks that reflect the investigation of different stages of a single phenomenon.

A new aspect in physics methodology is the issue of the scientific organization of work (SOW) during laboratory work, which is discussed by O.G. Galytskyi, M.V. Hadetskyi, and V.G. Kulish [186].

These authors proceed from the following premise: the primary focus is on developing a pedagogical approach in which each student must identify and recognize the potential within their own learning process – particularly that which lies in self-organization – thereby facilitating the transition from a teacher-directed learning system to a self-directed one.

The implementation of such learning requires the development of students' skills and abilities in the scientific organization of their academic work, as a set of skills that, under optimal conditions, ensure the active involvement of students in practical activities as agents managing these activities, and the rational organization of all its components with sufficiently high effectiveness.

In terms of addressing the issue of improving methods for conducting physics laboratory work, the following skills related to the scientific organization of work (SOW) are essential for students:

1. The ability to identify and set goals and objectives for future learning activities.

2. The ability to determine the content of educational activities in accordance with these goals.

3. The ability to select methods (ways and means) for carrying out educational activities.

4. The ability to plan the organization of educational activities.

5. The ability to conduct self-monitoring and self-assessment of the results of educational activities.

The basic structure of students' activities during laboratory work can be presented as follows:

1) clarifying (considering) the objectives of the work;

2) developing a plan for conducting the experiment;

3) selecting the necessary equipment and experimental setup;

4) conducting the experiment and recording the results of observations and measurements;

5) analyzing the results of the experiment.

To successfully develop students' skills in the National Educational Program (NEP), the teacher must first analyze the structure of the organizational cycle and the structure of student activities during laboratory sessions and based on this, methodically ensure the transformation of NEP elements into active student engagement while conducting physics experiments.

This is illustrated by the preparation and conduct of the laboratory work "Determination of the Electron Charge" by 10th-grade students.

Students are given the following homework assignment in advance: using the textbook and based on the lab assignment, answer the following questions:

1) Based on the experiment plan, state the objective of the experiment;

2) Based on the theoretical material used in this experiment, specify the specific conditions, methods, and means for achieving the objective;

3) Create your own experiment plan in the form of a table;

4) Identify possible methods for monitoring and evaluating the results of the work;

5) Suggest efficient ways and means to minimize time spent on the work.

Discussing answers that reflect the operational composition of skills in the NEP, based on specific content from the laboratory work, is an effective method for expanding the scope of students' activities and helping them identify connections between individual skills within the complex.

After that, guided by the structure of the procedure for conducting a physics experiment and their own plan, the students begin the laboratory work.

As they carry out the work, they make brief notes reflecting the sequence of practical steps in accordance with the planned procedure, presented in tabular form.

We will outline only the structure of the plan without describing the students' specific actions.

Plan structure (presented in a column, with another column alongside it describing the students' actions – their responses): 1) purpose of the experiment; 2) hypothesis on which the experiment is based; 3) experimental conditions; 4) observations during the experiment; 5) measurement of quantities; 6) equipment and materials required for the experiment; 7) sequence of the experiment; 8) format for recording experimental results; 9) setup diagram; 10) conducting the experiment and measuring physical quantities during the experiment, recording them; 11) calculation of the sought quantities; 12) calculation of measurement errors; 13) analysis of the experimental results; 14) conclusions based on the results of the experiment.

In summarizing the history of the development of methods for organizing and conducting group laboratory work in physics at general secondary education institutions, we can identify trends that should be considered when seeking ways to improve the educational process in accordance with the concept of general education in Ukraine.

1. One of the trends in the development of views on the organization and conduct of physics laboratory work is the desire to organize them in a way that maximizes students' creative independence under the given specific conditions.

This is confirmed by the fact that the educational community periodically turns its attention to the problems of developing students' independence, thinking, and creative abilities.

The introduction of laboratory work into physics education in schools in the United States and England led to its subsequent adoption in Western European countries, particularly in France and Germany.

The role of these laboratory exercises was defined as follows:

The main provisions of the instructions for the Harvard List of Laboratory Exercises (U.S., 1887) included: "during laboratory work, the student is in the position of a researcher"; "students should not be told what new things they will see".

The Circular of the Department of Public Education (Scotland, 1898) states:

"Each student individually and independently investigates a specific laboratory task; as for the teacher's lectures and demonstrations, they should be given a secondary role".

In the 1920s, in certain schools in many countries around the world – England, Japan, China, India, Norway, and others – the Dalton Plan was used, which, regardless of its overall evaluation, aimed to foster in students independence, the ability to organize their work, and to conduct it using the research method.

In the 1960s and 1970s, in all the constituent republics of the USSR, the focus of society and the educational community was on developing students' active participation and independence in the learning process, particularly during laboratory work, and, in connection with the introduction of problem-based learning, on developing students' creative abilities.

In the 1990s and now in the 21st century, many Ukrainian physics educators have focused their attention on identifying teaching methods that would facilitate the organization of creative laboratory work (Vovkotrub V.B., Vovkotrub V.P. – 1994, Kotelnikov G.F. – 1996, Kryskov A.A., Kryskov D.A. – 1997, Galatyuk Y.M., Voitovich I.S., Ostapchuk M.V. – 2000, and others).

Thus, conducting whole-class laboratory work in physics in secondary schools is one of the means of developing students' creative activity, which corresponds to the concept of the modern educational process, the main goal of which is the formation and development of students' individual characteristics.

2. The division of physics classes in the early years of its use in education into classroom and laboratory sessions, and, at the same time, the use of whole-class laboratory work, reflected different views on the organization of students' educational activities.

In the years that followed, classroom-based laboratory work became more widespread, but during the period of enthusiasm for the Dalton Plan, preference was given to laboratory work.

Finally, in the domestic system of physics education, laboratory work was divided into two groups – classroom-based laboratory work and physics practicum work, each of which had its own objectives and, accordingly, its own methodology.

A distinctive feature of classroom-based laboratory work is that it is integrated into the process of studying the relevant curriculum material as an integral part organically linked to other components of this process.

Attempts to conduct laboratory work designated by the curriculum as classroom-based in the form of a practical workshop (Shatalov V.F., 1995) did not gain widespread acceptance in physics education practice or in the works of physics educators.

3. The fact that laboratory work is a method of learning about physical phenomena that focuses on students' productive activities – independence in studying certain characteristics of phenomena and their patterns – does not preclude direct or indirect guidance of students' actions by the teacher, nor does it mean that all student actions must be conscious rather than merely mechanical reproductions of actions that have been instructed or even demonstrated to them.

Thus, conducting whole-class laboratory work involves creating conditions for students to be aware of the objectives (goals) of the work; its progress; the actions to be performed; and the results of the work.

The foundations of the traditional approach to organizing student learning during group laboratory work were laid as early as the beginning of the 20th century.

In 1907, French professor François Dewalve described the "procedure" for laboratory work as follows: "First, tasks are presented to the students; then, to teach them to experiment, the teacher asks them how they plan to set up the experiment and gradually guides them in the right direction. The students then offer their comments and ask questions. Only after this do they begin the experiments, which usually last 30 – 35 minutes. The remaining time is devoted to calculating the obtained result. Then the teacher again begins to guide them and discuss the results with them. At home, in their free time, the students describe the entire exercise in detail in a separate notebook".

The best option for this method of organizing and conducting laboratory work is the teacher's verbal instruction before the activity.

Students' research work during laboratory sessions was guided by various types of written instructions found in "Workbooks" (1920s).

These instructions, in a modified form, were first included in school physics textbooks, and from the late 1990s in Ukraine, in the so-called "physics workbooks."

In this case, students' independence was linked to their actions with the apparatus: the student consciously sets up an experimental setup with a specific goal; reproduces the process that interests them; by analyzing the results, they confirm the validity and objectivity of physical phenomena and patterns.

This approach to organizing and conducting classroom laboratory work effectively fails to harness its full potential for shaping and developing students' personalities, which are characterized by: active engagement; creative independence; and broad cognitive capabilities.

This has led to conflicting views on this type of educational activity for students.

4. The path to resolving conflicting views regarding the improvement of methods for organizing and conducting laboratory work was defined by an integrative model of the educational process, the foundations of which were laid by V.I. Kalenyk.

As early as 1965, it was noted: 1) all proposals by physics teachers and methodologists regarding the improvement of laboratory work can be agreed upon if one considers not the methodology of laboratory work in general, but its individual groups; 2) the activities of teachers and students during laboratory work should be evaluated in terms of their contribution to the development of students' skills in the experimental study of the surrounding world.

In 1986, the basic principles for structuring the educational process were formulated based on an integrative model, according to which classroom laboratory work is part of a cycle of the educational process in which a component of the school physics curriculum (a unit of this content) is studied and mastered. That is, the organization and conduct of classroom laboratory work must be analyzed by considering the lessons preceding and following the laboratory session, as well as other classes, including students' homework.

Under these conditions, the proposals of Ukrainian physics educators regarding the organization of creative laboratory work become clear. These proposals are aimed at increasing students' independence at all stages of a classroom physics experiment: identifying and understanding the learning problem, planning the experiment (including formulating hypotheses); conducting the experiment (including testing the hypothesis); and processing and presenting the experimental results. After all, all these stages of the experiment define the essence of the ability to conduct independent experimentation.

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