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THE EDUCATIONAL AND COGNITIVE ROLE OF LABORATORY WORK IN MASTERING COMPLEX CONCEPTS OF THE PHYSICS COURSE

***[1]Kabalci I., [2]Taimuratova L.U., [2]Kobenov A. N.**
[1]Uşak University, Uşak, Türkiye
[2]Yessenov University, Aktau, Kazakhstan
e-mail: idris.kabalci@usak.edu.tr, lidiya.taimuratova@yu.edu.kz,
anuar2.kobenov@yu.edu.kz

Abstract. This work examines the role and significance of laboratory work in the teaching of physics. The study demonstrates that laboratory experiments contribute to consolidating students' theoretical knowledge, developing practical skills, and forming research-oriented thinking. The pedagogical and psychological aspects of laboratory work are analyzed, and the stages of its organization are outlined: preparation, performing the experiment, processing results, and drawing conclusions. The didactic functions of laboratory work-visualization, consolidation, assessment, developmental, and educational functions are described. In connection with the introduction of STEM and STEAM approaches into the modern education system, the effectiveness of enhancing the content of physics laboratory work with digital technologies has been demonstrated. It is noted that virtual laboratories and computer modeling allow students to conduct experiments in a safe and engaging way. The study results show that laboratory work is an important methodological tool for mastering complex physical concepts, increasing students' interest in the subject, and developing scientific thinking.

Keywords: physics, laboratory work, experiment, teaching methodology, research skills, STEM, STEAM, virtual laboratory.

Introduction.

Today, the education system is viewed as a key factor in the socio-economic development of society. The main goal of 21st-century education is to develop individuals who can think creatively, analyze scientific information, and make independent decisions. To achieve this goal, it is necessary not to limit the teaching process to theoretical knowledge alone but to involve students in active learning activities. Such activity is primarily realized through learning forms on experimentation and research. Among natural science disciplines, physics occupies a special place because it explains the essence of natural phenomena and requires experimental verification. The presence of many abstract concepts in physics creates difficulties in fully understanding the material. For example, concepts such as electric field(E), magnetic field(B), wave, induction, and the law of conservation of energy cannot be fully explained only theoretically. Therefore, mastering these concepts through concrete experiments is one of the main methodological requirements in teaching physics [1].

In this regard, laboratory work is an integral part of teaching physics. It is not just a method of conducting experiments but also a powerful tool that develops students' cognitive activity, logical thinking, creativity, and research skills.

The main feature of teaching physics is that theoretical laws can be verified through experiments. In this subject, experimentation plays a special role: it is not only a source of knowledge but also a main tool for forming and testing knowledge. Laboratory work is a process in which a student understands a physical law through hands-on activity. During such work, the student measures physical quantities, operates instruments, processes data, and draws conclusions. Thus, instead of receiving ready-made information, the student comprehends it through personal experience. Laboratory work activates students' cognitive activity through: clarification of knowledge through direct observation and measurement;

- increased cognitive interest;
- independent analysis and interpretation of experimental results;
- linking theoretical concepts with practical experience

These features prove that laboratory work not only provides subject-specific knowledge but also forms research-oriented thinking [2].

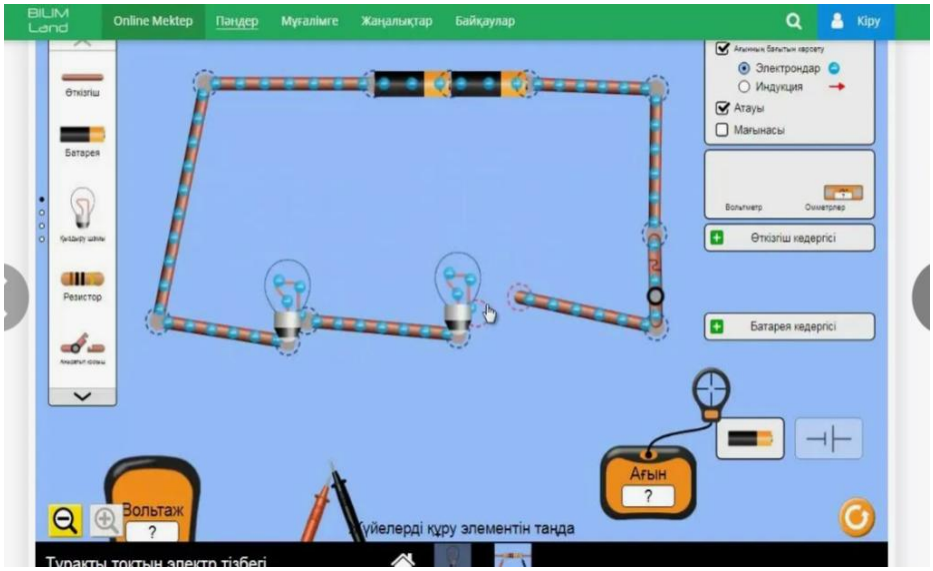

Figure 1. laboratory work

Organizing laboratory work requires not only methodological skill but also knowledge of pedagogical and psychological principles. From a pedagogical point of view, laboratory work is an effective way of involving students in active learning.

It shifts the learning process from the model “teacher – source of knowledge” to “student – seeker, researcher.” This approach is consistent with constructivist learning theory: knowledge is not given in a ready-made form but is constructed through the student’s actions and experience (J. Bruner, J. Piaget) [3]. From a psychological perspective, a laboratory experiment develops the student’s attention, memory, logical thinking, and willpower. During each experiment, the student:

- identifies a problem,
- Searches for ways to solve it,
- Manipulates instruments,
- analyzes results,
- draws conclusions.

This is the classical logic of scientific research. Therefore, students who frequently perform laboratory work develop research culture, experimental thinking, and scientific reasoning.

In physics education, laboratory work is divided into several types depending on content and purpose. Each type has its own educational benefits. For example, demonstration experiments reinforce the principle of visual learning, while individual laboratory work enhances student independence.

Students often have difficulty understanding abstract concepts in physics, such as:

- electric field, which is invisible and understood only through its effects;
- magnetic field, represented only through field lines;
- wave processes, which propagate in space and time and cannot be directly observed;
- quantum phenomena, which occur in the micro-world and can be demonstrated only through modeling.

In mastering such complex concepts, laboratory work plays an important role because it connects theory with factual evidence. For example, when explaining the law of electromagnetic induction, observing the appearance of an electric current when a coil is moved in a magnetic field

allows students to deeply understand the theory. Similarly, demonstrating interference and diffraction of light helps confirm the correctness of wave theory.

Laboratory work has wide didactic functions: Visualization: demonstrates theory with concrete experiments;

Consolidation: allows practice-based reinforcement of knowledge;

Assessment: checks students' knowledge and skills;

Development: enhances thinking, analysis, comparison, and reasoning; Education: develops qualities such as accuracy, discipline, and responsibility.

Thus, laboratory work can be used at all stages of the learning process—explaining new material, reinforcing it, and evaluating learning [4].

With the introduction of STEM and STEAM concepts, physics laboratory work is becoming integrated with informatics, engineering, technology, and art. Students can build their own devices using the Arduino platform or study physical processes using computer simulations. In conclusion, laboratory work combines the theoretical and practical foundations of teaching physics. It increases students' cognitive activity and helps them deeply understand complex physical concepts. Effective use of laboratory work requires the teacher to consider not only its technical organization but also pedagogical and psychological aspects.

The method of organizing laboratory work includes the following stages:

1. Preliminary preparation Students are introduced to the objective and task of the laboratory work. The tools and safety rules are explained. A brief review of theoretical material is provided: formulas, laws, and key concepts related to the topic [5].

2. Performing the experiment Students work independently or in groups. All measurements and observations are carried out carefully. If needed, measurements are repeated to check accuracy.

3. Processing and analyzing results Experimental data are recorded in tables and graphs. Errors and their causes are identified. Comparison with theoretical models is carried out.

4. Drawing conclusions Achievement of the experiment's objective is evaluated. The relationship between theory and experimental results is identified. Students present and discuss their conclusions.

Each of these stages ensures the educational effectiveness of laboratory work and develops student's logical thinking. Laboratory work serves as a basic component of students' cognitive activity, covering the process from perceiving knowledge to experimentally verifying it.

Linking theory with practice: For example, when studying mechanical oscillations, students compare the theoretically calculated period with the measured one.

Learning through hands-on experimentation: Because many physics concepts are abstract, theoretical explanation alone is insufficient. For example, understanding electric current through Ohm's law becomes clearer when measuring voltage and current directly. Developing independent thinking and research skills: During experiments, students independently choose methods, evaluate results, and draw conclusions. These skills contribute to lifelong scientific thinking. Developing error-analysis skills: Differences in measurements and inconsistencies in data teach students to analyze information critically. They learn to generalize data and draw correct conclusions [6,7,8].

In physics courses, several experimental methods are used, each having its own impact on students' cognitive activity: measurement using instruments, observation and comparison, modeling when real demonstration is impossible, demonstration experiments conducted by the teacher, independent project-based experiments [9,10].

Laboratory work plays a crucial role in increasing students' motivation. Motivation is enhanced by:

- practical relevance,
- Engaging and dynamic experimental processes,
- the possibility of drawing personal conclusions.

For example, experiments on light diffraction using different gratings increase student engagement. They compare results for different grating spacing's and verify theoretical predictions.

Learning outcomes from laboratory work can be assessed based on several criteria:

- understanding theoretical laws and applying them in practice,

• skillful use of instruments and measurement accuracy,

• ability to analyze data and draw conclusions,

• Creativity and research initiative.

Assessment results help teachers evaluate lesson effectiveness, identify students' strengths and weaknesses, and plan future lessons.

In modern education, integrating laboratory work with digital technologies is essential. Virtual and online laboratories, simulations, and computer modeling provide safe and visual experimentation.

For example:

• physical models offer visual representation of complex systems;

• data analysis software outputs graphs and error calculations;

• interactive simulations illustrate atomic and molecular processes.

These methods develop research skills, increase interest in physics, and help master complex concepts.

Conclusion. The study results show that laboratory work plays an essential role in teaching complex physics concepts. The initial hypothesis that laboratory experiments significantly improve student's theoretical understanding was fully confirmed. The main findings are:

• Reinforcement of theoretical knowledge: students verify theory experimentally, such as comparing calculated and measured oscillation periods.

• Development of practical skills: students learn to handle instruments and make accurate measurements [11].

• Formation of research thinking: students analyze data, identify errors, and draw conclusions.

• Increased motivation: hands-on experiments enhance interest and responsibility.

• Advantages in the learning process: clarification of abstract concepts, learning through experience, development of creativity, teamwork skills, and the effectiveness of digital tools.

Thus, laboratory work strengthens theoretical learning, develops practical and research skills, increases motivation, and integrates modern digital technologies into physics education.

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ФИЗИКА КУРСЫНЫҢ КҮРДЕЛІ ҰҒЫМДАРЫН МЕҢГЕРУДЕГІ ЗЕРТХАНАЛЫҚ ЖҰМЫСТЫҢ ОҚУ-ТАНЫМДЫҚ РӨЛІ

***[1]Кабалжи И., [2]Таймуратова Л.У., [2]Кобенов А. Н**.
[1]Ушак университеті, Ушак, Түркия
[2]Есенов Университеті, Ақтау, Қазақстан
e-mail: idris.kabalci@usak.edu.tr, lidiya.taimuratova@yu.edu.kz,
anuar2.kobenov@yu.edu.kz

Аңдатпа. Бұл жұмыста физика пәнін оқытуда зертханалық жұмыстардың рөлі мен маңызы қарастырылған. Зерттеу барысында зертханалық тәжірибелердің оқушылардың теориялық білімін бекітуге, тәжірибелік дағдыларын дамытуға және зерттеушілік ойлау қабілетін қалыптастыруға ықпал ететіні дәлелденді. Жұмыста зертханалық жұмыстың педагогикалық және психологиялық аспектілері талданып, оны ұйымдастырудың кезеңдері көрсетілген: дайындық, экспериментті орындау, нәтижелерді өңдеу және қорытынды шығару. Сондай-ақ зертханалық жұмыстардың дидактикалық функциялары – көрнекілік, бекіту, бақылау, дамытушылық және тәрбиелік қызметтері сипатталған. Қазіргі білім беру жүйесіндегі STEM және STEAM бағыттарының енгізілуіне байланысты физикалық зертханалық жұмыстардың мазмұнын цифрлық технологиялармен толықтырудың тиімділігі дәлелденген. Виртуалды зертханалармен компьютерлік модельдеу әдістері оқушылардың қауіпсіз әрі қызықты тәжірибе жасауына мүмкіндік беретіні атап өтілген. Зерттеу нәтижелері көрсеткендей, зертханалық жұмыстар күрделі физикалық ұғымдарды меңгеруде, оқушылардың пәнге деген қызығушылығын арттыруда және ғылыми тұрғыдан ойлау қабілетін дамытуде маңызды әдістемелік құрал болып табылады.

Түйін сөздер: физика, зертханалық жұмыс, тәжірибе, оқыту әдістемесі, зерттеушілік дағды, STEM, STEAM, виртуалды лаборатория.

УЧЕБНО-ПОЗНАВАТЕЛЬНАЯ РОЛЬ ЛАБОРАТОРНОЙ РАБОТЫ В ОСВОЕНИИ СЛОЖНЫХ ПОНЯТИЙ КУРСА ФИЗИКИ

***[1]Кабалжи, И., [2]Таймуратова Л. У., [2]Кобенов А. Н.**
[1]Университет Ушак, Ушак, Турция
[2]Университет Есенова, Актау, Казахстан
e-mail: idris.kabalci@usak.edu.tr, lidiya.taimuratova@yu.edu.kz,
anuar2.kobenov@yu.edu.kz

Аннотация. В данной работе рассматривается роль и значение лабораторных работ при изучении физики. В ходе исследования было доказано, что лабораторные опыты способствуют закреплению теоретических знаний учащихся, развитию практических навыков и формированию исследовательского мышления. В работе проанализированы педагогические и психологические аспекты лабораторной работы, показаны этапы ее организации: подготовка, выполнение эксперимента, обработка результатов и подведение итогов. Также описаны Дидактические функции лабораторных работ – наглядная, закрепляющая, Контрольная, развивающая и воспитательная. В связи с введением направлений STEM и STEAM в современной системе образования доказана эффективность дополнения содержания физических лабораторных работ цифровыми технологиями. Отмечается, что методы компьютерного моделирования с виртуальными лабораториями позволяют учащимся создавать безопасные и интересные эксперименты. Результаты исследования показали, что лабораторные работы являются важным методическим пособием в освоении сложных физических понятий, повышении интереса учащихся к предмету и развитии способности к научному мышлению.

Ключевые слова: физика, лабораторная работа, практика, методика обучения, исследовательские навыки, STEM, STEAM, виртуальная лаборатория.