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Milliy Pedagogika
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- 13.00.00 Pedagogika fanlari
- 13.00.01 Pedagogika nazariyasi. Pedagogik ta'limotlar tarixi
- 13.00.02 Ta'lim va tarbiya nazariyasi va metodikasi (sohalar bo'yicha)
- 13.00.03 Maxsus pedagogika
- 13.00.04 Jismoniy tarbiya va sport mashg'ulotlari nazariyasi va metodikasi
- 13.00.05 Kasb-hunar ta'limi nazariyasi va metodikasi
- 13.00.06 Elektron ta'lim nazariyasi va metodikasi (ta'lim sohaları va bosqichlari bo'yicha)
- 13.00.07 Ta'limda menejment
- 13.00.08 Maktabgacha ta'lim va tarbiya nazariyasi va metodikasi
- 13.00.09 Ijtimoiy pedagogika
- 07.00.00 Tarix fanlari
- 19.00.00 Psixologiya fanlari
- 01.00.00 Fizika-matematika fanlari
- 02.00.00 Kimyo fanlari
- 03.00.00 Biologiya fanlari
- 09.00.00 Falsafa fanlari
- 10.00.00 Filologiya fanlari
- 11.00.00 Geografiya fanlari

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Pedagogika, psixologiya fanlariga ixtisoslashgan ilmiy jurnal



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EDUCATIONAL PHYSICS EXPERIMENTS: METHODS AND DIDACTIC STRATEGIES FOR DEVELOPING CRITICAL THINKING IN STUDENTS

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Abstract: This paper examines the didactic potential of problem-based physics experiments in fostering critical thinking among students. The study analyzes strategies for designing learning situations in which students' initial assumptions or common preconceptions are challenged by experimental evidence. A structured approach to planning experimental activities is proposed, aimed at developing skills in hypothesis formulation and verification, critical evaluation of experimental methods and data, and the construction of logically grounded arguments. The article presents representative examples of problem-based experiments from various fields of the physics curriculum. The findings are intended for physics teachers, educational methodologists, and developers of instructional programs.

Key words: scientific process, cognitive conflict, hypothesis, verification, problem-based learning, educational experiment, critical thinking, physics education.

Annotatsiya: Ushbu maqolada muammoli fizik tajribalar asosida ta'lim jarayonini tashkil etishning o'quvchilarda tanqidiy fikrlashni shakllantirishdagi didaktik imkoniyatlari tahlil qilinadi. Tadqiqot jarayonida o'quvchilarning dastlabki tasavvurlari yoki umumiy qarashlari tajriba natijalari orqali zidlashtiriladigan ta'limiy vaziyatlarni loyihalash strategiyalari yoritilgan. Tajribaviy faoliyatni rejalashtirishning tizimli modeli taklif etilib, u gipoteza yaratish va tekshirish, tajriba usullari va olingan ma'lumotlarni tanqidiy baholash hamda mantiqan asoslangan xulosalar chiqarish ko'nikmalarini rivojlantirishga yo'naltirilgan. Maqolada fizika ta'limining turli bo'limlariga oid muammoli tajribalar misollari keltirilgan. Tadqiqot natijalari fizika fani o'qituvchilari, metodistlar va o'quv dasturlari ishlab chiquvchilar uchun mo'ljallangan.

Kalit so'zlar: ilmiy jarayon, kognitiv ziddiyat, gipoteza, verifikatsiya, muammoli ta'lim, o'quv tajribasi, tanqidiy fikrlash, fizika ta'limi.

Аннотация: В статье рассматривается дидактический потенциал проблемно-ориентированных физических экспериментов в формировании критического мышления обучающихся. Анализируются стратегии проектирования учебных ситуаций, в которых первоначальные представления или распространённые взгляды учащихся опровергаются результатами экспериментальных исследований. Предлагается структурированный подход к планированию экспериментальной деятельности, направленный на развитие умений формулирования и проверки гипотез, критической оценки экспериментальных методов и данных, а также построения логически обоснованных выводов. В работе приведены примеры проблемных физических экспериментов из различных разделов школьного курса физики. Материалы статьи адресованы учителям физики, педагогам-методистам и разработчикам образовательных программ.

Ключевые слова: научный процесс, когнитивный конфликт, гипотеза, верификация, проблемное обучение, учебный эксперимент, критическое мышление, физическое образование.

INTRODUCTION

One of the most important skills in today's environment, which is filled with conflicting information, is the capacity for critical thinking. There is considerable potential for developing this skill within an experimentally based school physics course. Nevertheless, this potential is rarely fully realized through conventional laboratory work, which is often algorithmic and illustrative in nature. To effectively foster critical thinking, a transition to problem-based experimentation is required, in which results are not immediately apparent and instead demand intellectual investigation from students.

A key characteristic of a problem-based experiment is that it creates a cognitive conflict between common-sense assumptions and scientific explanations, lacks a predetermined outcome known to students, requires the formulation and evaluation of multiple hypotheses, and encourages critical examination of experimental condi-



tions as well as the quality of the collected data. Through participation in such experiments, students experience all stages of scientific inquiry and move from being passive followers of instructions to active researchers engaged in analytical and reflective thinking.

LITERATURE REVIEW

The theoretical foundations of problem-based learning are deeply rooted in pedagogical and psychological research, emphasizing the role of intellectual challenges in the development of students' thinking skills. One of the most influential contributions to this approach was made by I. Ya. Lerner, who in his 1974 work demonstrated that learning becomes more effective when students are placed in problem situations that require independent reasoning and active knowledge construction. This idea was further developed by A. M. Matyushkin, who in his 2008 research highlighted the significance of problem situations as a means of stimulating cognitive activity and creative thought, particularly through the experience of cognitive conflict and hypothesis testing.

An important psychological perspective on learning tasks was introduced by G. A. Ball, who in his 1990 study analyzed educational tasks as instruments for shaping intellectual operations and reflective thinking. From this standpoint, problem-based experiments can be viewed as structured learning tasks that engage students in the full cycle of scientific inquiry. The methodological implications of this approach for physics education were comprehensively examined by V. A. Orlov and G. G. Nikiforov in 2015, who emphasized the didactic value of experimental activity when it goes beyond algorithmic procedures and encourages analytical reasoning, comparison of assumptions, and critical evaluation of results.

The development of critical thinking as a central educational outcome has been extensively discussed by D. Halpern, whose 2000 work outlined key cognitive skills required for effective reasoning, such as analysis, evaluation, and self-regulation. In the context of physics education, these ideas are practically realized through problem-based experiments. M. A. Shchukin, in his 2021 article, demonstrated that problem-oriented experimental activities in school physics lessons significantly enhance students' ability to question data, identify sources of error, and reflect on the reliability of experimental results. Together, these studies provide a solid theoretical and methodological basis for understanding educational physics experiments as an effective tool for fostering critical thinking in students.

RESEARCH METHODOLOGY

The organization of a problem-based experiment is grounded in creating learning situations in which opposing viewpoints are deliberately confronted. In such scenarios, the instructor structures a lesson that stimulates cognitive conflict and motivates students to engage in analytical reasoning. A typical example of this approach is the experiment known as "Falling Bodies in Air," which poses the question of which object will fall first: a crumpled paper ball, a coin, or a flat sheet of paper. When formulating hypotheses, students usually rely on their everyday experiences and propose different assumptions, such as all bodies falling at the same rate, the influence of shape on the falling speed, or the idea that a heavier object falls faster. All hypotheses, including those that later prove to be incorrect, are systematically recorded.

At the next stage, students focus on planning the experiment and verifying the proposed hypotheses, during which they learn to critically assess the verification process itself. Particular attention is given to key questions concerning the testability of assumptions, the identification of measurable quantities, the elimination of random factors, and the adequacy of experimental conditions. In the context of the falling bodies experiment, students analyze the influence of air resistance, propose methods to ensure the simultaneous release of objects, and eventually arrive at the idea of comparing fall times. To increase the level of complexity, the instructor may suggest conducting the experiment in an elongated tube with partial air evacuation, thereby deepening students' understanding of experimental design and control variables.

ANALYSIS AND RESULTS

Although students collect empirical data during the experiment, the primary emphasis is placed on their critical interpretation of the results. A key instructional technique applied at this stage is referred to as "doubting the data," in which the instructor deliberately creates situations that require analytical and reflective thinking. For example, in a thermodynamics experiment, the efficiency of an electric kettle is measured and is found to be 120%. Such a result becomes the basis for scientific discussion rather than being accepted at face value. From the perspective of the law of conservation of energy, students are encouraged to question whether this outcome is physically possible, to identify potential sources of error, to consider whether heat losses to the environment were taken into account, to assess the accuracy of power measurements, and to evaluate whether the measuring instruments were properly calibrated. As a result, students come to understand that experimental



data must always be critically reflected upon and verified, rather than merely recorded, even when the outcome appears incorrect.

At the conclusion and reflection stage, the entire research cycle is subjected to critical evaluation. Students analyze which hypotheses were confirmed and why certain initial assumptions proved to be incorrect. They identify sources of experimental error, discuss possible improvements to the methodology, and assess the overall reliability of the obtained results. This reflective process strengthens their ability to evaluate not only experimental outcomes but also their own reasoning and decision-making strategies throughout the inquiry.

To further illustrate the effectiveness of problem-based experiments, examples from various fields of physics are presented. In mechanics, the experiment known as “The Riddle of Two Carts” involves two carts connected by a thread and a compressed spring. When the thread is burned, students are asked to predict the motion of the carts if their masses are equal and to analyze what happens when one cart has a significantly greater mass. A common misconception is that the heavier cart will move more slowly or remain stationary. The experimental results provide a clear basis for understanding the principle of conservation of momentum and demonstrate that the magnitudes of the acquired momenta are equal.

In thermodynamics, the “Melting Ice” experiment considers two identical beakers filled with water at 40°C. One beaker contains a piece of ice at 0°C, while the other contains an equally massive piece of ice at -20°C. Students are asked to determine which beaker will have cooler water after the ice has melted. Many instinctively select the second option; however, the experiment demonstrates the crucial importance of accounting for all the heat required to warm the ice from -20°C to 0°C before melting occurs.

In electrodynamics, the “Circuit with an Electrolyte” experiment involves constructing an electrical circuit using a power supply, a lightbulb, and a bottle of distilled water. When the circuit is completed, the bulb does not light, prompting students to explain why this occurs. They are then asked to predict what will happen if table salt is added to the water. This experiment reveals a frequent oversight in students’ hypotheses, namely the failure to consider the role of free charge carriers. Through observation and analysis, the phenomena of electrolytic dissociation and the dependence of electrical conductivity on the presence of ions are clearly demonstrated.

CONCLUSION AND RECOMMENDATIONS

Structured as a research cycle, the problem-based physics experiment represents an effective approach to fostering critical thinking. It encourages students to question apparent phenomena, to develop and test ideas, to tolerate uncertainty, and—most importantly—to critically evaluate their own reasoning and the information they collect. Through this process, students acquire not only a set of physical principles but also a deeper understanding of the scientific method, which forms a fundamental basis for their future academic and professional development across disciplines.

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- 13.00.00 Pedagogika fanlari
 - 13.00.01 Pedagogika nazariyasi. Pedagogik ta'limotlar tarixi
 - 13.00.02 Ta'lim va tarbiya nazariyasi va metodikasi (sohalar bo'yicha)
 - 13.00.03 Maxsus pedagogika
 - 13.00.04 Jismoniy tarbiya va sport mashg'ulotlari nazariyasi va metodikasi
 - 13.00.05 Kasb-hunar ta'limi nazariyasi va metodikasi
 - 13.00.06 Elektron ta'lim nazariyasi va metodikasi (ta'lim sohaları va bosqichlari bo'yicha)
 - 13.00.07 Ta'limda menejment
 - 13.00.08 Maktabgacha ta'lim va tarbiya nazariyasi va metodikasi
 - 13.00.09 Ijtimoiy pedagogika
 - 07.00.00 Tarix fanlari
 - 19.00.00 Psixologiya fanlari
 - 01.00.00 Fizika-matematika fanlari
 - 02.00.00 Kimyo fanlari
 - 03.00.00 Biologiya fanlari
 - 09.00.00 Falsafa fanlari
 - 10.00.00 Filologiya fanlari
 - 11.00.00 Geografiya fanlari



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