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METHODOLOGY FOR DEVELOPING STUDENTS' THINKING USING PARADOXES OF PHYSICS

МЕТОДИКА РАЗВИТИЯ МЫШЛЕНИЯ СТУДЕНТОВ С ИСПОЛЬЗОВАНИЕМ ПАРАДОКСОВ ФИЗИКИ

Abstract:

The article is dedicated to the possible solutions of paradoxes, their discussion and their use within the framework of university education. Each paradox of physics contains two contradictory arguments, and by showing that one of the arguments contains an error, it eliminates the supposed contradiction, and this is what is called the resolution of the paradox.

In the paper, it is presented that discussions of possible solutions to paradoxes are one of the important areas of contemporary scientific research and higher education. Actually, paradoxes are resolved by refining the definition of the relevant concept.

Since ancient times, paradoxes have occupied the minds of the best thinkers of mankind, and their solution is associated with serious epistemological difficulties. Analyzing paradoxes is an excellent way to train and develop students' ability to think independently.

The work is considering the methodology of using paradoxes of physics in the university course. The activation of students' interest in the subject of physics through the paradoxes of physics, the paradoxes as the focus of students' attention on the studied topic, the development of independent thinking during the discussion of paradoxes are discussed.

Keywords: paradoxes of physics, methodology, independent thinking, creative thinking, wave-particle duality, Schrödinger's cat

Аннотация:

Статья посвящена возможным решениям парадоксов, их обсуждению и использованию в рамках университетского образования. Каждый парадокс физики содержит два противоречащих друг другу аргумента, и, показывая, что один из аргументов содержит ошибку, устраняется предполагаемое противоречие, что и называется разрешением парадокса.

В статье представлено, что обсуждение возможных решений парадоксов является одним из важных направлений современных научных исследований и высшего образования. Собственно, парадоксы разрешаются разъясняя определения соответствующего понятия.

С древних времен парадоксы занимали умы лучших мыслителей человечества, и их решение связано с серьезными гносеологическими трудностями. Анализ парадоксов - отличный способ тренировать и развивать способность студентов мыслить независимо.

В работе рассматривается методология использования физических парадоксов в университетском курсе. Обсуждается активизация интереса учащихся к предмету физики через парадоксы физики, парадоксы как фокус внимания учащихся на изучаемой теме, развитие самостоятельного мышления при обсуждении парадоксов.

Ключевые слова: парадоксы физики, методология, самостоятельное мышление, инновационное мышление, корпускулярно-волновой дуализм, кот Шрёдингера

1. Introduction

As it is said in one of the most repeated quotes of famous physicist Richard Feynman: "What I am going to tell you about is what we teach our physics students in the third or fourth year of graduate school. It is my task to convince you not to turn away because you don't understand it. You see, my physics students don't understand it. That is because I don't understand it. Nobody does."

The article states the thesis about the usual interpretation of independent thinking as originality. The discussion in the article leads to the conclusion that the category of innovative thinking will be really effective if the main characteristic of the creativity were not originality but rather the ability to independent problem solving. The paper presents the optimal steps for an independent solution of research problems. The work introduces the idea of "paradoxes of physics" for developing students` thinking.

The characteristic feature of innovation is that the innovative product enjoys extraordinary demand. From that characteristic follows the second important aspect of innovative ideas, that of being extremely profitable. It is time to realize that the young generation needs to be educated on innovation and think independently. Indeed, the best investment is the education of the younger generation [1, 2].

It is rightly emphasized that the basis of innovative thinking is independent thinking. The ability to think independently is formed thanks to the rich experience of solving school problems. Indeed, if a student is able to solve problems for which there is no algorithmic way of solving them, then his thinking is independent and, to that same extent, innovative [3-5].

Non-standard solutions to problems, new ideas, creative thinking, and innovative approaches are important in successful education.

The development of students' thinking is primarily due to the introduction of significant innovative ideas, including the effective use of fundamental knowledge of physics and artificial intelligence [1, 6-7]. It follows from this that the primary task is to form competitive, motivated students, to develop and implement innovative solutions.

Solving that problem requires building the innovative thinking skills of students. In order to achieve that goal, it is necessary to develop innovative thinking approaches and methods [8-9].

2. Methodology for developing students independent thinking

Generations of students are the most important foundation for innovation. As their thinking improves, the effectiveness and productivity of innovations in education will steadily increase.

Nowadays, innovative thinking is considered the crown bearer of human thinking. This truth is reflected in a well-known proverb: a new idea is actually an old well forgotten one. It remains to add that the old solution leads to the new solution through the bridge of similarity [4].

Over the last decades, the emerging trends of globalization and international cooperation based on a common educational environment have caused significant changes in the field of educational organization principles. Meanwhile, the modern education system should be focused on the creation of a cognitive algorithm, critical understanding, forming research skills, and willingness to innovate. At the same time, interactive and participatory education is brought to the fore as a basis for creating an educational environment for the new generation of students [10-12].

Having the first, fundamental role of information technologies for the innovative education of the new generation of students and improving their impact, along with the expansion of existing tools, will continue to work to increase the effectiveness of innovations in education.

Each methodological research crowns the efforts of a whole generation of scientists. The task is quite modest: to present arguments and facts in favor of the article.

Any extraordinary idea that will be accepted by the scientific community is patiently explained and intensively discussed, first of all, by the ingenious author of the idea and his talented associates. In fact, by explaining a new idea, we are building a bridge that connects a new unusual concept with old, generally accepted, habitual knowledge. To connect existing knowledge and a new idea is to find a path that leads from the available information on this issue to a new concept.

Any reasonable explanation of a great discovery shows us a possible way in which, in principle, this discovery could be achieved by some analogy [13-15].

As if these outlandish ideas weren't enough, eminent scientists rushed to try out truly "crazy" ideas to uncover the holiness of the natural world [4].

3. Paradoxes of physics for activating students' interest toward physics

Physics is the natural science of matter, involving the study of matter, its fundamental constituents, its motion and behavior through space and time, and the related entities of energy and force [16]. Physics is one of the most fundamental scientific disciplines, with its main goal being to understand how the universe behaves [17].

Until today, the logic of human thinking was mainly developed as the theory of proof and argumentation. And because the immediate subject of that theory were the forms of thought, then starting with the great Aristotle, the logical monographs were also focused on the formal side of thinking, overshadowing the goals and problems of scientific research and creative thought.

That's why the article considers paradoxes of physics.

The Paradox of the Uncertainty Principle

Albert Einstein, the great revolutionary of science, never accepted the theory of quantum mechanics that was being formed during his lifetime. He was convinced that through a mental experiment he would be able to discover such a contradiction or paradox in the foundations of quantum mechanics that would force him to abandon the theory of atomic physics. One of the "refuting" thought experiments was published by the Einstein-Podolsky-Rosen trio. The content of that mental experiment is as follows. A particle C has split into two identical particles A and B. Knowing the momentum P_C of particle C and measuring with any precision the momentum P_A of particle A, according to the law of conservation of momentum we can determine with the same precision the momentum of particle B: $P_B = P_C - P_A$. At the same time, we can also measure the coordinate of particle B with any accuracy, which contradicts one of the foundations of quantum mechanics, the Heisenberg uncertainty principle, according to which it is not possible to measure the particle's momentum and coordinate with any degree of accuracy [17].

The solution to the paradox. The authors of the presented thought experiment did not take into account that by measuring the coordinate of particle B, they affect this particle and

introduce uncertainty into its calculated coordinate. That is, they cannot measure the momentum and coordinate of particle B with any degree of accuracy (see [18, 19]).

The paradox of "wave-particle duality".

In 1900, Planck discovered that in order to explain the distribution laws of electromagnetic energy, it is necessary to accept that energy is radiated in discrete quantities, called quanta. In 1905, Einstein discovered that in order to explain the patterns of the photo effect, it is necessary to assume that light energy is also absorbed in discrete quantities, as if light were composed of particles (later called photons). Already in the 1910s, the view that light has both wave and particle properties was established and widely accepted in the community of physicists. And if the physicists of that region were asked: "and don't you worry about the fact that wave and particle properties are incompatible?", they would readily agree that this "philosophical" question will be answered in future physics.

The problem of combining wave and particle properties became even more important when Louis de Broglie's view gained recognition in 1924 that each of the atomic particles (electron, proton, neutron, atomic nucleus as a whole, etc.) has a wave property whose length is inversely proportional to to the mass (more precisely, the momentum) of the particle. Nevertheless, the question formulated above was still unanswered. "And it doesn't bother you that wave and particle properties are incompatible?" Now we can formulate the paradox of the principle of wave-particle duality.

Experiments confirm that in the atomic world waves exhibit particle properties, particles exhibit wave properties, but the question of how to combine the incompatible particle and wave properties remains unanswered for common sense.

The solution to the paradox. All this became clear in 1926, when Max Born proposed the following interpretation of the wave function in the theory of quantum mechanics: in quantum mechanics, the probability of physical quantities (energy, momentum, etc.) at a given point in space and at a given moment in time is determined by means of a wave function. The wave function is not a physical wave, but a means of quantitative calculations of physical quantities. In this way, the electron, being involved in the atom, does not become a wave of electric charge. Using the wave function, we can calculate the energy, momentum, etc. of the electron state in an atom [20].

Schrödinger's wave function paradox

Schrödinger's wave function is the basic mathematical tool that physicists use to conveniently and accurately calculate all investigated quantities in the world of atoms and molecules. The Schrödin-Geryan theory of the atom is rightly called "wave mechanics".

Historically, the paradox arose when trying to answer the following natural question: "What is the physical meaning of the wave function?" *Schrödinger's* answer was, one might say, straightforward. Since the state of electrons in an atom is accurately described by a wave function, it must be accepted that an electron in an atom is a wave of electric charge. But how does that wave of electric charge maintain itself outside the atom? Schrödinger could not give a satisfactory answer to the last question.

The solution to the paradox. It was in a debate with Schrödinger that Max Born in 1926 put forward quite convincingly the idea that the meaning of the wave function is that it estimates the probability of physical quantities within the atom, and in the atomic world in general.

"Schrödinger's Cat"

The "Schrödinger's Cat" thought experiment was proposed by Erwin Schrödinger, wanting to demonstrate the flawed nature of quantum mechanics. The scheme of that mental experiment is as follows: a cat, a bottle full of poisonous gas and a mechanism using

radioactive material are placed in a closed tank. The radioactive material is chosen in such a way that one of its nuclei can split within one hour with a probability of 1/2. When one of the nuclei of the radioactive material splits, it will lead to the fact that the mechanism will work, the cat will be lifeless.

Since the basis of mental experience is the splitting of the nucleus, the description of which is carried out by the wave function, it seems natural that the state of the cat is also described by the wave function. And this will mean that the condition of the cat will be described with some probability. The possible description of the cat's condition can be expressed in an imprecise but descriptive expression: "The cat is both alive and inanimate." From our point of view of common sense, a cat must be either alive or inanimate. The presented disconnect between our reasoning and the figurative language used is seen by some commentators as a flaw in quantum mechanics.

A solution to the paradox. The above-mentioned metaphor attributed to quantum mechanics "a cat is both living and nonliving" is so far from a scientific interpretation that the scientific experiment described above is extremely difficult to qualify as a paradox. However, let's note that the probability assessment of the observed phenomenon, for example, the outcome of a given football game, has meaning only before the moment of its occurrence (in our example, before the end of the game). After a cat has become inanimate, it is also pointless to judge: "a cat is both alive and inanimate" [2].

Scientific research begins with a question that interests the given scientist either because the answer is not yet known, or because the accepted answer to that question does not satisfy him. In fact, the process of choosing a research problem is somewhat elementary in nature. First, the research problem is often directly presented to the young scientist by his scientific supervisor. On the other hand, a scientist in his life and activities on one occasion or another encounters various unsolved problems, gets acquainted with opinions and approaches to solving them to varying degrees.

Paradoxes are presented as factors that strongly strengthen the interest of students. This is especially true for the most impressive classical paradoxes and the indifference of scientists to the paradoxes of physics.

In the article, the discussion of the paradoxes of physics leads to the conclusion that the category of independent thinking will be really effective if students can develop the ability to independently explore and solve problems.

4. Conclusion

In the process of teaching academic disciplines, lecturers actively use methods for solving paradoxes, which allow not only to obtain theoretical and methodological knowledge about the basics of research activities, the rules for performing, designing and presenting the results of various educational, research and scientific and production works, but also help to structure information field about the achievements of various disciplines affecting the problems of the development of the logic and methodology of science, and, thereby, to see the relationship and interdependence of the problems solved in science, which is an important part of preparing students of various fields and profiles.

The article analyzes the possible solutions of some paradoxes. Particular attention in this article is given to the use of the paradox technique in university courses, by activating students' interests in physics, with the help of paradoxes of physics, and just developing students' independent thinking. In this regard, there are considered paradoxes of physics as a way of focusing students' attention on the topic under study. In the course of the discussion of ways to solve paradoxes, a methodology for the development of independent thinking of students was developed.

There is also a section devoted to predictive questions for developing students' independent thinking. This helps to improve the development of independent thinking of students in the system of university education. Therefore, the possible solutions and

discussions of paradoxes of physics, and the methodology of their use in the university course were presented.

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