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APPLICATION OF SYSTEMIC ANALYSIS AND SYNERGETIC APPROACHES IN TEACHING PHYSICS AT HIGHER EDUCATION INSTITUTIONS

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ABSTRACT: The article sheds light on the theoretical and methodological foundations for applying systems analysis and synergetic approaches in physics education. It is shown that systems analysis allows for the study of physical processes as a unified system composed of interrelated elements, while the synergetic approach serves to understand the laws of self-organization, order, and instability in complex open systems. The article analyzes the crystallization process, the phenomena of paramagnetism and ferromagnetism, the self-assembly of nanoparticles, and the formation of graphene and carbon nanotubes from a systematic-synergetic perspective. The research results show that this approach is of great importance in physics education for developing students' logical and creative thinking and research skills, as well as for linking theoretical knowledge with practice.

KEYWORDS: systems analysis, system, system elements, wholeness, totality, consistency, synergistic approach, self-organization, ferromagnetic, fluctuations, bifurcation points.

INTRODUCTION

In the current era of rapid globalization and digital technology development, the higher education system is tasked with preparing highly qualified specialists who can think independently and are capable of developing innovative ideas. This requires introducing modern pedagogical approaches into the educational process. In particular, teaching physics places great importance on linking students' theoretical knowledge with practical application and on developing their ability to understand and analyze complex processes.

Physics, as a fundamental science that studies natural phenomena and processes, demands systematic thinking. From this perspective, using systematic analysis and synergetic approaches in physics education is considered an important tool for enhancing educational effectiveness. While systematic analysis allows for the study of physical processes as a system of interrelated elements, the synergistic approach helps in understanding the laws of self-organization and development in complex systems.

This article analyzes the importance of systemic analysis and synergetic approaches in teaching physics at higher education institutions, the methods for applying them to the educational process, and their pedagogical effectiveness.

MAIN PART

Systems analysis is a method of studying a specific object or process as a set of interconnected elements. In teaching physics, this approach helps to view phenomena in nature as an integrated system. Teaching based on systems analysis develops students' logical and systematic thinking abilities, helps them understand the cause-and-effect relationships between physical processes, and fosters the skill of applying theoretical knowledge to practice. skills in independent analysis and problem-solving are developed.

Synergetics is an interdisciplinary field that studies the laws of self-organization and development in complex systems. It is intrinsically linked with physics, mathematics, biology, pedagogy, and information technology. In physics education, a synergistic approach allows for the development of students' creative thinking, the integration of knowledge, and the strengthening of interdisciplinary connections. Through this approach, students gain a deep understanding of the dynamic nature of physical processes and the states of stability and instability in systems.

Knowing the synergistic categories is important for understanding the essence of the synergistic approach. Synergetics studies the laws of self-organization in complex nonlinear systems. Self-organization, nonlinearity, fluctuations, bifurcation points, emergent properties, and others are considered the main concepts or categories of synergetics.

Let's examine how certain physical processes can be explained from the standpoint of systematic analysis and synergistic approaches. For example, let's analyze the crystallization process of liquids. As is well known, from the standpoint of simple physical concepts, when liquids cool, the molecules' kinetic energy decreases, the particles begin to form an ordered lattice, and as a result a crystal emerges. From the perspective of systems analysis and a synergistic approach, this process is further explained through parameters of collective motion and order. Liquids and solutions can be viewed as open systems in thermal and mass disequilibrium with the external environment. During crystallization, the liquid exchanges energy with the external environment—that is, it releases heat to the surroundings, its temperature drops, and the system leaves thermodynamic equilibrium. Within the liquid there are always microscopic fluctuations, i.e., random density variations. As the temperature approaches a certain critical point, in some local regions the molecules begin to arrange themselves in an ordered way, and small "crystallite nuclei (seeds)" appears. Which of these fluctuations grows depends on randomness and environmental conditions. The order parameter is one of the key concepts in synergetics, and as a parameter it represents the degree of spatial ordering of the molecules, one can consider concepts such as symmetry, periodicity of density, and so on. In the liquid state, the order parameter is equal to zero, whereas it is nonzero when a crystal forms.

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This signifies a phase transition. When the temperature reaches a certain value, i.e., at the bifurcation point, the system becomes unstable. At that point, the system "chooses" one of two paths: remaining in the liquid state or transitioning to the crystalline state. This phenomenon is called bifurcation in synergetics. The crystal forms spontaneously without external intervention. In this process, molecules collectively choose the most stable configuration through local interactions, meaning that global order emerges in the system as a result of the interactions among its many elements.

A systems-synergetic approach makes it possible to provide a more general and deeper explanation of phase transitions in systems, the emergence of order, the relationship between chaos and order, and the dynamics of nonequilibrium systems. Therefore, crystallization is not only a thermodynamic process but also a pattern of collective self-organization. Viewing the crystallization of liquids from the perspective of dissipative structures, this process is understood as the formation of an ordered spatial structure in an out-of-equilibrium system through energy and matter exchange with the external environment and a decrease in entropy.

The magnetic properties of materials can also be analyzed through a systematic and synergistic approach. In a systematic analysis, a material is viewed not as a mere collection of individual atoms but as an integrated system of interconnected elements. In systems analysis, matter is not regarded as a mere collection of individual atoms but as an integrated system composed of interconnected elements. From a synergistic perspective, each atom in a paramagnetic substance can be regarded as a small element of the system, the external magnetic field as a controlling parameter, and the orientation of the magnetic moments as the system's state. In the absence of an external field, the magnetic moments in a paramagnetic substance are randomly oriented, and the system's entropy reaches its maximum value. When an external field is present, atoms interact with each other and with the field, a collective alignment in a statistically determined direction occurs, and a partially ordered structure is formed. In a paramagnetic material, this order is weak and transient, and if the field is removed, thermal motion restores disorder. In a paramagnetic material, there is no strong, self-sustaining collective correlation; order is maintained only in the presence of an external field.

According to a systematic and synergistic approach, ferromagnetism is not a property of individual atoms but rather a collective, self-organizing characteristic of a multi-element system. Here, mutual cooperation—i.e., coherence—emerges among the spins; at the critical point, order appears, domains form, and a new macroscopic property—magnetization—arises. Therefore, ferromagnetism is a prime example of a synergetic phenomenon of order emerging from chaos.

From a synergetics perspective, a ferromagnetic material can be viewed as an open system exchanging energy and momentum with its external environment.

In simple models of ferromagnets, the system is often assumed to be closed or near equilibrium. However, in synergetics, the primary focus is on factors such as the system's interaction with the external environment, non-equilibrium states, self-organization, collective effects, and phase transitions. In a ferromagnet, near the Curie temperature, the spins align collectively. This process is considered a classic example of “self-organization” in synergetics. For example, the influence of an external magnetic field, heat exchange, energy dissipation, spin waves, and the emergence of fluctuations necessitate considering the system in an open state. Small fluctuations around the Curie point can affect the macroscopic magnetization of the entire system. This corresponds to the concept of an “order parameter” in synergetics. In ferromagnets, self-organization occurs through the ordering of the atomic magnetic moments. This phenomenon is primarily explained by the exchange interaction in quantum mechanics. Atoms possess magnetic moments. In ferromagnetic materials, each atom is regarded as a small “magnet” due to the spins of its electrons.

If the temperature is above the Curie point, thermal motion randomizes the atomic magnetic moments in different directions, creating disorder. As a result, the overall magnetization is nearly zero. At temperatures below the Curie point, the exchange interaction between neighboring atoms strengthens, causing their spins to align in the same direction. In certain regions of the crystal, millions of atoms become magnetized in the same direction. The energy tends to reach its minimum.

The system divides into domains to minimize its energy. Within each domain, the magnetic moments are aligned in the same direction, making the domain itself strongly magnetized. This is the primary hallmark of self-organization, as internal order emerges even in the absence of an external field.

In condensed matter physics, a systematic approach to teaching nanostructures views the object under study as a system composed of interrelated elements. For nanotechnology, this means taking into account the interrelationships among atomic, nano, micro, and macro levels, as well as their structural, functional, and energetic properties, it means viewing the object not in isolation but in relation to its environment and the conditions under which it arises. For example, the properties of a quantum dot are determined not only by its material but also by its shape, size, matrix, and external field.

Нанозарраларнинг ўз-ўзини йиғиши, сиртларда наноструктураларнинг шаклланиши, квант ўлчовли эффектларнинг пайдо бўлиши, наноматериалларнинг коллектив хаттиҳаракати синергетик жараёнларнинг нанотехнологияда намоён бўлишини англатади. Масалан олтин нанозарраларининг ўз-ўзини йиғиши, углерод нанонайчаларининг ўсиши, графен қатламларининг шаклланиши, квант нуқталар, иплар ва ўраларнинг ҳосил бўлиши нанотехнолгияда кузатиладиган синергетик ҳодисалар ҳисобланади.

Тизимли-синергетик ёндашув усули физик ҳодиса ва жараёнларни is a modern methodology that enables effective teaching, because it views objects as complex, open, self-organizing systems, provides interdisciplinary integrated education, fosters deep understanding of processes occurring at the micro and nano scales, and helps develop creative and inquisitive thinking.

CONCLUSION

The use of systems analysis and synergetic approaches in teaching physics at higher education institutions is considered one of the important factors in increasing educational effectiveness. These approaches contribute to the development of students' logical, analytical, and creative thinking skills.

While systems analysis allows for an understanding of physical processes as a whole system, the synergistic approach helps in understanding the mechanisms of interaction and self-organization in complex processes. As a result, students develop competencies in independent learning, analysis, and the development of innovative solutions.

Moreover, integrating these approaches with information and communication technologies, virtual laboratories, and interactive methods further enhances the quality of physics education. This, in turn, plays a crucial role in preparing competitive, highly qualified personnel.

The application of a systematic-synergetic approach to the teaching process enables students to understand the nature of nonlinear processes at the macro, micro, and nanoscale levels and to master methods for analyzing complex systems. skills in creating interdisciplinary models, the ability to predict changes in objects when conditions change, and their scientific research competence and innovative thinking are developed.

REFERENCES

1. Ishmuhamedov R., Abduqodirov A. Ta’limda innovatsion texnologiyalar. – Toshkent: “Fan va texnologiya”, 2018. – 256 b.
2. Hakimov Q. Sinergetika asoslari va ta’lim tizimida qo‘llash masalalari // *Pedagogik ta’lim*. – 2020. – №3. – B. 45–52.
3. Saidov S., YUldashev B. Tizimli tahlil va pedagogik jarayon modellari // *Zamonaviy ta’lim*. – 2019. – №6. – B. 18–25.
4. Tursunov P. Fizika o‘qitish metodikasi. – Toshkent: O‘qituvchi, 2017. – 320 b.

5. Tolipov O'., Usmonboeva M. Pedagogik texnologiyalarning amaliy asoslari. – Toshkent: "Fan", 2016. – 280 b.

6. Haken H. Synergetics: Introduction and Advanced Topics. – Berlin: Springer, 2004. – 758 p.

7. Norqulov H. Oliy ta'limda fizika fanini o'qitishning innovatsion usullari // *Fizika, matematika va informatika*. – 2021. – №2. – B. 33–39.

8. Alimov A. Ta'limda tizimli yondashuvning nazariy asoslari // *Xalq ta'limi*. – 2018. – №4. – B. 12–19.

9. Prigogine I., Stengers I. Order out of Chaos: Man's New Dialogue with Nature. – New York: Bantam Books, 1984. – 349 p.

10. Qurbonov SH. Oliy ta'lim pedagogikasi. – Toshkent: "Ma'naviyat", 2015. – 410 b.

11. Abdullaev N. Murakkab tizimlar nazariyasi va ta'lim jarayoni // *Ilmiy axborotnoma*. – 2022. – №1. – B. 55–61.

12. Baransev R. G. Sinergetika v sovremennom estestvoznanii. M.: Editorial URSS, 2003.

13. Samoorganizatsiya v prirode./ Pod red. V.A. Dmitrienko. Vipusk 1. - Tomsk: Izd-vo TGU, 1997. S. 188.