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Development Of A Didactic Model Based On Information Technologies In Teaching Semiconductor Physics

Valiyev Ulugbek Kadirovich

senior lecturer, department of physics, AndSU, Uzbekistan

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Abstract: This article examines the theoretical and methodological foundations for developing a didactic model for teaching semiconductor physics using modern information technologies. The aim of the study is to improve the learning effectiveness of complex physics concepts and processes through the integration of digital learning tools, virtual laboratories, and simulation models. The proposed model is based on the principles of system-activity, constructivist, and cognitive approaches and fosters students' spatial-imaginative and exploratory thinking. An experiment confirmed that the use of digital platforms and interactive visualization tools facilitates a deep understanding of charge transfer phenomena, band structure, and recombination processes in semiconductor materials. The practical significance of the study lies in the potential application of the proposed model in the development of e-courses, training modules, and virtual laboratories in the disciplines of Solid State Physics and Semiconductor Physics.

Keywords: Semiconductor physics, didactic model, information technology, virtual laboratory, visualization, spatial thinking, digital learning.

Introduction: Modern engineering education requires the implementation of innovative approaches to teaching fundamental disciplines, particularly semiconductor physics. The rapid development of nanotechnology, microelectronics, and photonics necessitates the development of not only theoretical knowledge but also practical skills in analyzing physical processes at the micro- and nanoscale. Traditional teaching methods are insufficiently effective for understanding concepts such as band structure, p-n junctions, recombination, and charge carrier generation. Under these conditions, information and communication technologies (ICT), enabling visual modeling and virtual experimentation, are particularly important. The aim of this study is to develop and scientifically substantiate a didactic model for teaching semiconductor physics based on the integration of ICT, which enhances students' cognitive activity, develops their spatial-imaginative thinking, and develops research competencies. The paper analyzes the psychological and pedagogical foundations of the formation of a conceptual apparatus in technical training, the approaches of V. Vygotsky, B. Lomov, R. Arnheim, as well as modern models of digital learning (connectivism, cognitive visualization, hybrid environments).

Although the issue of modernization of physics education has been comprehensively covered in many studies, practice shows that existing solutions often do not give full results due to the lack of harmony between the content of the subject, the methodological model and the measurement system. This section analyzes the problem by its components and proposes solutions; at the same time, a comparative approach is proposed based on existing literature (Uzbek, Russian and CIS schools).

METHODS

The didactic foundations of this model are combined with Comenius' principles and the progressive ideas of innovative educators. Their views on active learning, creating problematic situations, and developing students as active subjects are reimagined in the context of modern digital education. The proposed digital didactic model includes elements of virtual simulations, interactive assignments, and peer review. Group work is organized on online platforms, and at the final stage, the results are assessed in the form of a mini-poster or project presentation. This approach develops students' skills in independent thinking, reflection, and critical analysis, enhancing the effectiveness of the educational process.

The methodological concept of the study is based on the "goal-task-method-indicator-result" principle and involves organizing the subject "Semiconductor Physics" within a system based on information and communication technologies, focused on measurable results.

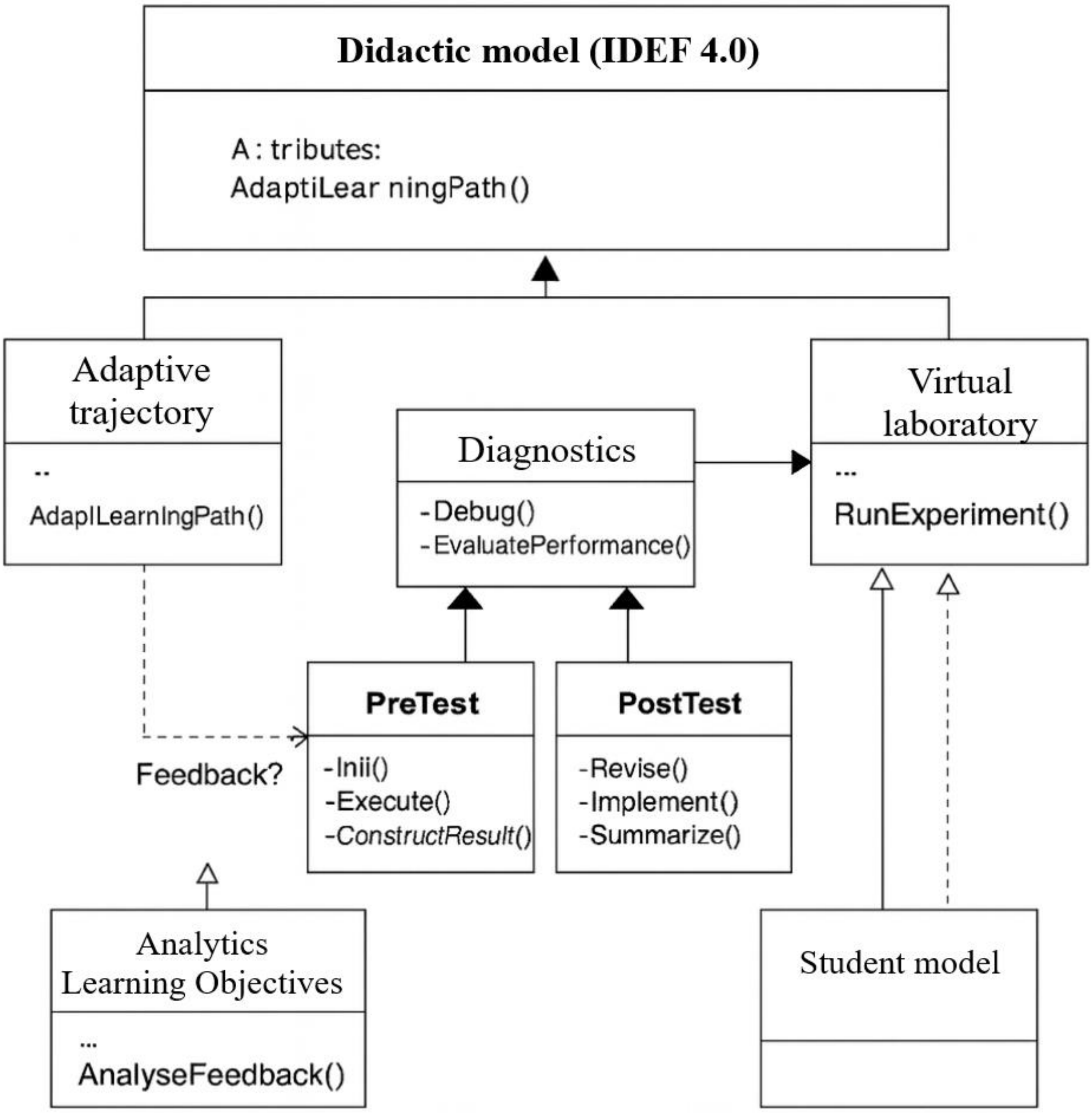

Figure 1. Didactic model for improving the methodology of teaching semiconductor physics

The core idea of the didactic model is to precisely model information flows and activity processes during the learning process and control each component based on mutual feedback. The model is based on the "Adaptive Trajectory" component, which differentiates student learning activities and adapts the learning process to their individual focus. The "Diagnostics" stage provides a basic level of preparation, while the "Virtual Laboratory" provides practical activities. The "Analytics" and "Evaluation" blocks analyze the resulting effectiveness of the learning process through measurable indicators. The model defines the input and output data for each stage. For example, during the diagnostic stage, the input data is the student's prior knowledge, and the output is their initial competency map. During the adaptive trajectory stage, the input data is the diagnostic results, and the output is the individual learning direction. Thus, all stages of the learning process are logically and continuously linked. This approach ensures the integrative and iterative nature of the educational system.

Another important aspect of the didactic model is maintaining continuous feedback between the instructor and the student. The teacher monitors students' performance via the online platform, analyzing their completed assignments, test results, and participation in virtual experiments. Students, in turn, have the opportunity to see the results of their work in real time and address any shortcomings. This approach makes the learning process transparent, manageable, and results-oriented.

RESULTS

An integrated educational environment based on interactive tools, multimedia animation, and digital educational resources for teaching semiconductor physics was developed. In this environment, educational materials, assignments, tests, and lab work are combined on a single digital platform. This integration allows students to independently learn, assess their knowledge, and manage the learning process in a personalized manner.

Using interactive modules, the platform:

• illustrates complex physical processes using visual animations,

• models semiconductor phenomena through virtual lab experiments,

• conducts diagnostic assessments using tests and exercises,

• helps students understand and manage their own thought processes based on a metacognitive learning model.

As a result, the developed system is emerging as an innovative educational ecosystem that integrates traditional education with the digital environment. This approach promotes the development of students' cognitive, metacognitive, and practical competencies, as well as enhances the effectiveness of physics learning.

Methodological models developed in previous studies are often limited to textual descriptions and do not clearly express their practical application. As a result, the teacher cannot quickly determine which didactic tool should be used at which stage of the learning process. Therefore, in this study, it was proposed to describe the methodological model in the form of a block diagram. The model includes the following main stages: diagnostics (identification of initial competencies), adaptive learning (electronic textbooks, short video lessons and simulations), practice (virtual laboratory and problem bank), reflection (learning journal and discussion) and assessment (final test and practical assignments). Input and output indicators for each block are clearly defined, which ensures transparency of the learning process.

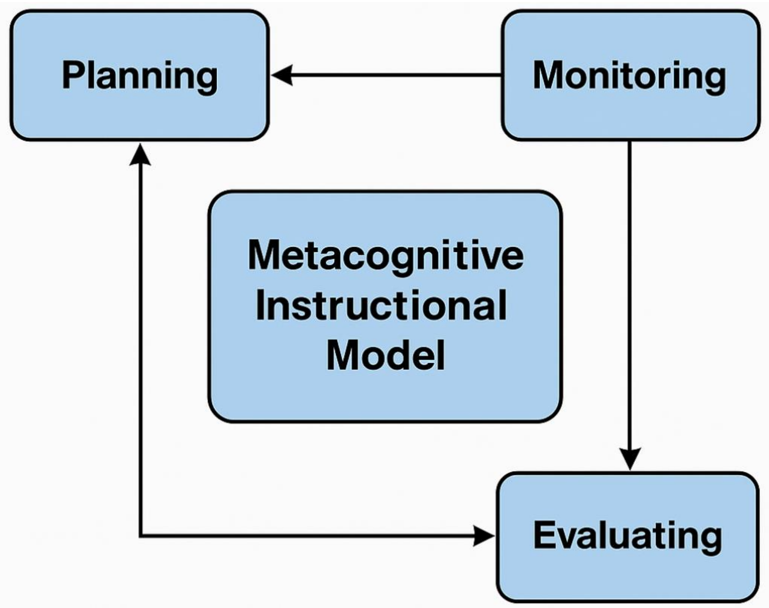

Figure 2. Metacognitive model for improving the methodology of teaching semiconductor physics

In the process of modernizing physics education based on innovative approaches, it is important to study the opinions of teachers and students. Because any new methodology or digital educational platform should, first of all, be based on the needs of the subjects participating in the educational process, their previously accumulated experience and practical problems. For this purpose, a survey was conducted within the framework of this study to identify ways to improve the effectiveness of teaching the subject "Semiconductor Physics". The results of the survey analyzed the opinions of teachers and students, the advantages and disadvantages of the existing teaching process, as well as the need for the use of innovative technologies in the educational process. During the study, the questionnaires were conducted in the electronic form of "Google Forms" and through audience interviews. A total of 78 students and 9 teachers participated. The content, form and results of the survey created an important analytical basis for improving teaching methods.

CONCLUSION

The developed didactic model for teaching semiconductor physics using information technology represents a holistic system, including:

The target component is focused on developing students' research and analytical competencies;

The content component is the integration of theoretical and virtual experimental modules;

The technological component is the use of digital simulators, virtual laboratories, and adaptive learning platforms;

The performance component is the improvement of conceptual understanding and the ability to model physical processes.

The implementation of the model in the educational process has demonstrated increased student motivation, independence, and awareness in the study of complex physical phenomena. Thus, the integration of information technology into the teaching of semiconductor physics facilitates the digital transformation of engineering education, making the learning process more interactive, exploratory, and competency-based.

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