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Use of Information Technology in Teaching Semiconductors Physics

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Abstract

Background/Objectives: The article discusses the possibility of studying the physics of semiconductors using information and communication technologies to improve teaching efficiency. **Methods/Statistical analysis:** For the study purposes, the authors have analyzed the content of semiconductor physics educational programs, the appropriateness of using information technologies in the study of the properties of semiconductors, and also 30 tests have been used. **Findings:** The authors have demonstrated the effectiveness of the course combining traditional and innovative educational technologies. The principal directions of the computer simulation use have been studied. The authors have presented four types of lessons based on the use of computer tools and have briefly described their features. The results of the control test have been shown, and based on these results the effectiveness of the semiconductors physics teaching has been analyzed. Teaching the semiconductors physics using a set of various modern computer technologies enhances the level of fundamental education of students, the formation of certain types of professional activities. **Applications/Improvements:** The study results show that the experimental group of students have more comprehensive and in-depth knowledge on the physics of semiconductors.

Keywords: Educational Activity, Information Technologies, Semiconductor Physics

1. Introduction

With the development of modern society, associated with quickly updating technologies, there are increased requirements for theoretical justification of pedagogical techniques determining the effectiveness of the learning process. The significance of technical literacy of education employees who know how to use means of information and communication technologies (ICT) in professional activities becomes higher. It becomes increasingly important to manage the educational process by using ICT tools in the educational activity. The role of the teacher in these circumstances is to ensure the effectiveness of educational work.

Studying the instrumental didactics, Steinberg[1] states that the tool-free teaching technique limits such important parameters as the stable results of education, controllability of the teaching process and influence of subjective factors. In improving the efficiency of teaching process the ICT become relevant didactic tools.

A growing number of physicists are studying technological innovations. In this regard, teachers are interested in information about the innovations that can be applied in the educational process.

Innovative technologies becoming more and more popular in the physics teaching and providing benefit to both the students and teachers are high-quality tool able to correct the traditional teaching. In teaching, an important role is played by the following: students' activities, interaction between teacher and student and a well-structured knowledge base.

It is necessary to focus on the use of interactive technologies as a tool for innovative teaching and learning in the educational environment. This will help the teacher to present the educational material in a more meaningful way. The use of the computer in the classroom

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for physics allows expanding the volume of the studied material and deeper understanding of the physical laws and phenomena where the physical processes cannot be observed directly through the eyes, in particular visualization of physical processes makes it possible to demonstrate the phenomena occurring in semiconductor materials.

Physics of semiconductors is a mandatory educational course for students specializing in microelectronics; this is a basis of engineering education, which provides implementation of professional work in the conditions when technologies become more and more complex. The experience of teaching "Physics of Semiconductors" shows that the study and the perception of the subject involve a number of difficulties: physics of semiconductors operates with a lot of abstract concepts, which complicates perception of material by students; in many cases, the visibility is insufficient and it is impossible to conduct an educational experiment. This leads to the fact that the students have short and shallow knowledge of the fundamentals of semiconductor physics, many students do not have a deep understanding of the phenomena, the processes described in this course. Therefore, to solve these problems, it is necessary to improve the methods of studying the theoretical framework of this course, to improve the selection of teaching material, the experimental support for the course with the use of new information technologies, to introduce new computer experiments.

2. Literature Review

Analysis of educational literature shows that many scientists have been paying great attention to the introduction of ICT in the educational process, techniques of ICT use the in some high school physics courses are developed. The fundamental education of students, as noted by Voznesenskaia[2], Latipov[3], Pichugin[4], Demin[5], Laktionov[6], Konovalets[7], Mironova[8], Shmeleva[9], Kutsenko[10], Fedorova[11], Cherkasskaya and others[12], may be fully realized only with the use of computer technologies. Information technologies are used in the study of quantum physics, applied in the teaching of "Special chapters of Solid State Physics" in the general physics course and developed in practical classes on the main sections of the general physics course. Computer models are used in the laboratory practicums of: Demina and Polugrudova[13] (atomic and nuclear physics laboratory works), Savateev[14] (use of computer models in the study of electromagnetic phenomena and processes). However, the problem of application of learning environments in semiconductors physics teaching has not been well studied yet. There is almost no theoretical and practical development of experimental support for the study of semiconductor physics using new information technologies. In order to determine what should be the method using the NIT means, it was necessary to consider ways to enhance the learning process, to render the education more illustrative and accessible, to improve the quality of independent activity of students through the use of the learning environment.

3. Results

The study identified ways to improve the efficiency of the use of information technology in the semiconductor physics teaching: the semiconductor physics educational materials requiring the use of computer experiments have been selected. For a deeper understanding of the electro-physical processes occurring in semiconductors, in the study of the physics of semiconductors, in terms of the use of ICT we advise to divide lessons into four groups: demonstration lessons, computer testing classes, training sessions and laboratory practicums.

During the demonstration lessons we used presentations concerning the following: proper conductivity and impurity conductivity of semiconductors; Hall effect; concentration of electrons and holes in semiconductors; current-voltage characteristics of p-n junction; semiconductor diode; semiconductor solar cell; semiconductor transistor.

In the computer testing classes, the computer testing programs were used in the course of which students obtained an explanation of its answers. For example, the question was: What is the position of the acceptor semiconductor on the Fermi energy level scale at a temperature much higher than the room temperature? There were four answer choices and after the selection of one of them, the screen displayed the result, followed by an explanation:

3.1 Close to the Conduction Band in the Forbidden Zone

It is not true because it is severely biased towards the conduction band. In this case, according to the Fermi-Dirac distribution, the conduction electrons must be much more than the holes, and at high temperature there is much more transitions between the valence band and the conduction band than the transitions to the acceptor level. At high temperature, the electrons and holes are formed mainly in pairs and their concentrations should be approximately equal. The Fermi level is located between the levels that lost the bigger number of electrons (at high temperature they are valence levels located at the top of the valence band) and the levels at which they arrived (at high temperature they are levels located at the bottom of the conduction band, impurity levels are neglected in these conditions). This condition corresponds to the middle part of the forbidden zone. And since the acceptor levels are still present, the Fermi level will be slightly biased towards them.

3.2 Close to the Conduction Band in the Conduction Band

It is not true because it is above the level of the conduction electrons occupied by electrons. In this case, the conduction electrons must be much more than the holes, and at high temperature there is much more transitions between the valence band and the conduction band than the transitions to the acceptor level, then the electrons and holes are formed mainly in pairs and their concentrations should be approximately equal. The Fermi level is located between the levels that lost the bigger number of electrons (at high temperature they are valence levels located at the top of the valence band) and the levels at which they arrived (at high temperature they are levels located at the bottom of the conduction band, impurity levels are neglected in these conditions). This condition corresponds to the middle part of the forbidden zone. And since the acceptor levels are still present, the Fermi level will be slightly biased towards them.

3.3 Close to the Valence Band in the Forbidden Zone

It is not true because it is severely biased towards the valence band.

In this case, the conduction electrons should be much less than the holes, and at high temperature there is much more transitions between the valence band and the conduction band than the transitions to the acceptor level, then the electrons and holes are formed mainly in pairs and their concentrations should be approximately equal. The Fermi level is located between the levels that lost the bigger number of electrons (at high temperature they are valence levels located at the top of the valence band) and the levels at which they arrived (at high temperature they are levels located at the bottom of the conduction band, impurity levels are neglected in these conditions). This condition corresponds to the middle part of the forbidden zone. And since the acceptor levels are still present, the Fermi level will be slightly biased towards them.

3.4 In the Middle Part of the Conduction Band

It is true, because the Fermi level is located between the levels that lost the bigger number of electrons (at high temperature they are valence levels located at the top of the valence band) and the levels at which they arrived (at high temperature they are levels located at the bottom of the conduction band, impurity levels are neglected in these conditions). This condition corresponds to the middle part of the forbidden zone. And since the acceptor levels are still present, the Fermi level will be slightly biased towards them. Therefore, when using this testing method, the educational and monitoring test functions are clearly manifested.

In the training classes, students practiced their semiconductor physics problem solving skills by means of special programs. In our case, we have used the Matlab Simulink program. This program allows students creating models and illustrating key concepts.

In laboratory practicums, at the same time, the features of computer laboratory practicums and realistic laboratory facilities were used. This method was used during the fulfillment of the following tasks: study of the current-voltage characteristics of the p-n-junction; determination of the semiconductor forbidden gap based on photo absorption; determination of the type of conduction of the semiconductor; study of the Hall effect in semiconductors; determination of the concentration of semiconductor materials. It is reasonable to use this method when during the performance of work it is necessary to explain and record processes and phenomena occurring in the microcosm level. Also the students were asked to perform "The Hall effect in impurity semiconductor" virtual laboratory work elaborated by us.

Experimental work was carried out at the Department of Physics in the Faculty of Sciences of Yasavi International Kazakh-Turkish University (Turkestan). It was attended by the second year students of the 5B011000-Physics specialty and the third year students of the 5B060400-Physics specialty, as well as by teachers of the department.

In the course of ascertaining stage of experimental work, the following was determined: current state of high school physical education, conditions of implementation of NIT in teaching the physics of semiconductors; feasibility of using NIT in semiconductor physics.

The experiment involved 67 students of the 3rd year. The course was divided into two classes. The first class comprised 33 students, and the second one comprised 34 students. In the first experimental class, the semiconductor physics course was taught using the method of ICT tools application developed by us, and the laboratory practicum was supplemented by five computer experiment demonstrations developed by us. In the second control class, the course was taught without use of computer technology.

At the beginning of the experiment, the level of students' knowledge in the field of semiconductor physics was examined. Average score in the control group was 3.47 and 3.45 in the experimental one.

Each semiconductor physics lecture in the control and experimental groups was evaluated by its efficiency as per the level of attention of students.

According to the analysis of the students' attention questionnaire results, it was found that 59% of students in the experimental group maintained a high level of attention throughout the lecture. In the control group, this value was only 26%.

The results of the learning of the educational material by students were tested by means of a control test. The test contained 30 questions on the physics of semiconductors, and the right answer should be picked from a set of four alternatives.

Results of the comparison of the quality of teaching of the experimental class and control class are presented graphically in Figure 1.

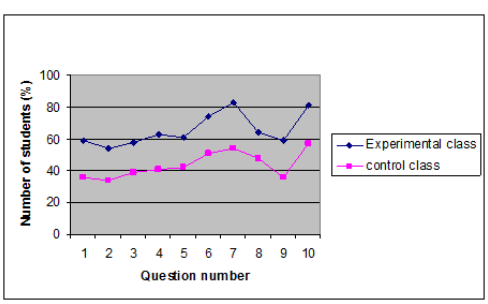

Figure 1. The students' test results.

Analysis of the test results has shown that 69% of experimental class students answered correctly the test questions, in the control class this value is 46%. This leads to the conclusion that the level of knowledge on the taught semiconductor physics material in the first group is more than 1.5 times higher than in the second one, which proves the effectiveness of the method used.

4. Discussion

The study has found that the educational process with the use of computer technologies requires the development and use of new approaches, ideas and teaching methods aimed at the improvement of the education content. Studies have shown that in the semiconductor physics teaching process, the modern information tools are used occasionally, mostly for solving traditional problems. Perhaps a limited use of computer technology is due to lack of software, lack of ready-made presentation materials corresponding to the education plans and pedagogical requirements.

During the study, teachers and students expressed a positive attitude towards the use of new computer technologies in education. However, as already noted, the information technologies in the semiconductor physics teaching are not fully used. In this regard, there is a contradiction between the demands of students, the requirements of modern society to the proper level of teaching, the use of information technologies in the learning activities and the lack of proper use of information technologies in the classroom. Thus the results of the study have shown the need to develop the structure of activity of the teacher regarding the use of information and communication tools at the lessons in order to increase their efficiency.

5. Conclusions

Based on the analysis of theoretical and experimental materials of the "Physics of Semiconductors" course the following aspects have been justified:

- the need for the use of ICT in the educational process in the study of physics of semiconductors, the place for such a use and the way to combine the model and full-scale experiments;
- a special role of computer models in the study of

physical phenomena associated with the lack of its demonstrativeness and difficulties in conducting full-scale experiment;

- the developed technique of creation and application of ICT at the lesson enhances its efficiency, as evidenced by the results of the experiment.

The use of information and communication tools in the educational process is of great importance and contributes to the quality of student education. The urgency of the issue on the use of ICT in education for the formation of professional competence of future specialists in all fields of activity requires further researches in this area and the development of ICT tools.

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