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Development of Polytechnic Knowledge and Abilities in the Course of Studying Physics

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ABSTRACT

In this article one of aspects of physics course studying improvement at high schools - the problem of the development of polytechnic knowledge and abilities in modern conditions - is revealed. In this research, the role and place of polytechnic education in the improvement of teaching physics at high schools are revealed, the main pedagogical requirements to polytechnic training of students at the present stage are defined. The work examines the contents of the physics course application component corresponding to the current state of science and technology, as well as the levels of formation of polytechnic abilities in physics at high schools under the conditions of modern production. The analysis of philosophical, psychology and pedagogical literature was used. The experimental work was performed in secondary schools No. 3, 5, 16 and 19 in Atyrau. The results obtained in the experimental classes, in comparison with the results of the control classes, prove that the application of the formation and development of polytechnic knowledge and skills of students during the study of a physics course technique, developed by us, leads to a significant extension and broadening of knowledge and skills of physics course students.

KEYWORDS
Innovative development; abilities formation levels; physical course; systematization principle

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Introduction

Under the conditions of industrial and innovative development, the school not only has to provide a certain amount of knowledge, but also to teach the future expert to think creatively, independently, to improve, update and develop knowledge. Nowadays, comprehensive high schools face a problem of training students possessing knowledge, corresponding to the last achievements of the scientific and technical progress.

The first element in the training of such personnel is the high school, the tasks of which at the present stage are defined as: to give each student profound knowledge of the bases of sciences, to establish a close connection between training and productive work, to improve the preparation of youth for work in the area of goods production, to help choose a profession reasonably. In this regard, special relevance is gained by problems of the development of

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polytechnic education of students in the course of training in physics under the conditions of modern production (Le Bellac, 2006).

The knowledge of polytechnic bases of the modern, intensively developing production not only will help the youth to quickly master this or that specialty, but will also make it professionally demanded and mobile. Polytechnic education implies the students' theoretical and practical familiarization with the main modern production principles, underlying the nature and society development laws; the formation of students' labor skills and abilities acts as a fundament for future professional training. This fully corresponds to the ideas of modern pedagogy (Slastenin, 2002), which associates polytechnic education with the solution of the following tasks:

a. students' familiarization with scientific laws, underlying material production;

b. students' development of abilities to apply acquired knowledge in various production areas;

c. students' fundamental mastery of basic production implements handling skills;

d. students' preparation for general labor activity, conscious choice of profession and specialization mastering.

Separate aspects of polytechnic education of students were investigated by many scientists during different periods of the development of pedagogical science. Polytechnicality problems were and remain one of main ones in pedagogical science and practice of comprehensive schools (Imashev, 2012).

The researches of A.I. Bugayev (1981), T.M. Shamalo & A.M. Mekhnin (2012) are dedicated to the issues, associated with polytechnic education within the general education physics course. General problems of education are examined in the works of H. Schunk & F. Pajares (2002), et al. Specific aspects of knowledge acquisition during education and development prospects have been investigated in the researches of J. Bennett (2003). Issues of education theory and practice have been studied in the works of J. A. Ross & P. Gray (2006). Knowledge actualization and practical skills formation during the process of studying school subjects are considered in the works of K. Dobson, J. Holman & M. Roberts (2001). The works of D. Gibbons-Wood & T. Lange (2000), are dedicated to researching modern tendencies in the development of physics education main skills. These works do not examine the issues of forming polytechnic knowledge and skills during the process of studying physics in secondary school. Various forms and methods of forming polytechnic knowledge and skills during the process of studying physics are presented insufficiently (Tulkibayeva, 1995).

The analysis carried out by us showed that there are still many unresolved and unsettled issues associated with the formation of polytechnic knowledge and abilities in teaching of sciences fundamentals at high schools.

Possibilities of the polytechnic principle implementation in studying physics are not fully realized, the knowledge and abilities formation level remains insufficient.

In our opinion, in this area, the following issues remain unresolved:

1. The contents and the principles of the selection of applied material reflecting physical bases of modern production.

2. The development of a complex of didactic means promoting the formation of polytechnic knowledge and abilities during the studying of physics at comprehensive high schools.

Nevertheless, this aspect, considering the problems of reforming comprehensive and vocational schools, has to find new scientific justification and practical solution. Within physics teaching, we consider the outdated polytechnic principle implementation technique and the low level of formation of polytechnic skills and abilities in students to be of utmost importance.

The use of specific methods and learning tools, forms of organization of training sessions are ultimately assigned to the aims and objectives of polytechnic education. Depending on the stage of formation of polytechnic knowledge and skills, they can be:

1. Familiarization of students with physical and technical principles of operation of individual technical objects and technological processes.

2. Compilation and systematization of polytechnic materials.

3. Mastery of the individual elements of polytechnic students' skills.

4. Testing of the system of polytechnic skills.

Selected methods and learning tools, forms of organization of training sessions are usually aimed at solving one goal (task) of the students polytechnic training (Norenkov & Zimin, 2004). Therefore, the solution of the problem under consideration generally requires the use of complex techniques and learning tools, forms of organization of training sessions. Using this complex makes it possible to form the creative activity of students and to include short-term practical tasks, improving the quality of polytechnic skills. At this point, the selection of an optimal learning algorithm is important (Imashev, 2012).

During the study of any general subjects, general labor skills of polytechnic nature can be formed in schoolchildren. Meanwhile, there is no clearly defined system of knowledge, skills and abilities that reflects the fundamentals of production in the curricula and textbooks on general subjects (Dewey, 1990). More specifically speaking, none of these programs contain a list of skills that students must master during the study of a particular academic subject. Polytechnic knowledge and skills, acquired by students during the study of the properties of liquids and solids, must be a specific system (Imashev et al., 2014).

System polytechnic skills in the physics course are determined by a combination of patterns studied by students, reflecting the general framework, principles of operation of modern technology. Formation of polytechnic skills in students begins with familiarizing them with the possible physical and

technical principles of the application of the phenomena, theories and laws as exemplified by individual technical subjects.

Thus, this task becomes the central problem of comprehensive high schools improvement, considering the prospects of acceleration of social, economic, scientific and technical progress (Zhazylbayeva & Salykbayeva, 2014). The relevance of this problem is caused by the integrative processes in school education, radical changes in the area of modern production of goods (Imashev, 2012).

Aim of the Study

The objective of the work is to define the contents and system of polytechnic knowledge and the abilities required to study physical bases of modern production and to develop innovative ways of promoting the reinforcement of a polytechnic orientation of training in physics.

Research question

What are the socioeconomic, organizational, and pedagogical conditions for improving the polytechnic education in secondary schools?

Methods

The experimental work was performed in secondary schools No. 3, 5, 16 and 19 in Atyrau.

The research was conducted in two stages, each pursuing specific goals. At the first stage (2010-2012), during the summative experiment, there were studied the states of students' polytechnic knowledge and skills, drafted texts of independent and testing works, aimed at assessing the knowledge and skills of 10th grade students, developed and specified, during the training process, physics lessons' systems and the methods of their application in the 10th grade. The teachers who worked in these classes were informed of the aims and tasks of the pedagogical experiment. Furthermore, they participated in the discussion regarding methodical guidelines for conducting lessons during physics studying.

At the second stage (2012-2014), the training experiment was conducted, wherein the authors analyzed the research results, based whereon general conclusions were made, according to the works' results. A quantitative assessment of training experiment results was performed by analyzing the practical works, performed by the 10th grade students, which were mainly developed and used at the first stage of the experimental work, as well as new testing works, which allowed to assess the polytechnic skills formation level.

Set of theoretical methods was used for the solution of research problems: the system analysis of philosophical, psychology and pedagogical literature on the studied problem, generalization and classification of pedagogical publications, the educational and methodical documentation analysis, design of systems and processes.

Data, Analysis, and Results

The polytechnic principle, which provides both the polytechnic content of educational subjects of the work of school students and a set of didactic teaching techniques aimed at the theoretical learning and mastering of this content by them, has to be the basis for teaching physics. In this regard, further

improvement of the polytechnic education of students, providing their theoretical and practical mastering of the general scientific bases and objects of modern production, with technicians as its major component, is necessary.

We made an attempt to create a structure of polytechnic material in physics according to the main areas of the scientific and technical progress. Such a system of the transfer of knowledge in the course of physics provides the possibility to observe a stricter sequence in the formation of polytechnic knowledge and abilities (Bugayev, 1981).

In the course of physics, the teacher brings the students to understanding of some important technical and economic tasks being solved in the country and the bases for further scientific and technical progress based on achievements of modern physics; deepens and expands practical skills of students, recognizing that politechnicality is the cornerstone of proper career guidance for children. For example, when studying molecular physics and electrodynamics, the teacher acquaints school students with physical issues of a power system and electrometallurgy, conducts physical experiments on the basis of some technological processes associated with properties of solid, liquid and gaseous bodies (Imashev, 2012b).

When studying thermodynamics, children learn the principle of operation of heat engines and a way to increase their efficiency. The teacher draws the attention of students to modern internal combustion engines, their difference from former ones and discusses with children related professions: driver, mechanic, car mechanic, engineer, etc. He then talks about the construction of thermal power plants. He reports that they use generally large 500 and 800 thousand kW blocks wherein high-performance vapors are used. It allows to achieve the highest efficiency and, therefore, to contribute to saving fuel and increasing labor productivity.

When studying properties of the liquids capillary phenomena application in technology, agriculture and life, the floatation process principle of enrichment of polymetallic and iron ores, which are used in iron and steel works, is considered. The teacher holds a discussion about the professions of dresser, magnetic separators operator, flotation operator, operator of mills, crushers, conveyors, acquaints students with the production of the iron concentrate, pellets, agglomerate.

While examining the passing of electric current through various environments, the teacher explains to students the physical bases of a number of technological processes (the use of electrolysis to receive aluminum and other non-ferrous metals, the application of electroplating, the spark discharge for metals processing and gases purification in electric precipitators, the arc discharge for welding of metal parts). When studying the material, the teacher holds consultation regarding the professions of people working with these

technological processes and draws the students' attention to the important role of the electrician in all branches of heavy and light industry, to various specializations, depending on the nature of production.

Special attention is paid to the studying of the construction of elements of radio equipment, automatic equipment and telemechanics (the vacuum diode and the triode, the electron beam tube, the light-dependent resistor, the semiconductor diode and the triode, etc.) (Dewey, 1990).

Within the methods structure of studying physics material, polytechnic material allows demonstrating the application of acquired knowledge in technology, everyday life and various productions. In order to explain the operation of any mechanism of device, it is necessary to involve numerous notions that were learned both recently and previously. Therefore, numerous internal disciplinary links while studying polytechnic material were used.

N.N. Tulkibayeva (1995) proved the multifunctional nature of the method involving the use of educational physical tasks, which allows applying the tasks to solve a wide range of methodological tasks, encountered by a teacher who organizes the educational process, which is why the multifunctional structure of tasks use in the educational process, alongside the tasks' education methods, is a type of internal disciplinary link. Solving tasks during lessons sometimes allows introducing new notions and formulas, determining learned patterns, approaching the presentation of new material. Algorithmic techniques, developed for a task class from a certain section, are used to solve tasks, which is why algorithms and algorithmic techniques of task solving are also a type of internal disciplinary link.

We have developed guidelines, which show the way to systematize polytechnic material in physics in the form of examples from different areas and encouraged to consider these examples in the classroom, which does not require spending additional time. The systematization of the material content of the polytechnics in physics corresponds to the principle of systematization of the high school material polytechnic physics course in the basic areas of scientific and technical progress and is its logical extension. The formation of polytechnic knowledge and skills while teaching physics is carried out by the relationship of the physical phenomena, laws and concepts of the scientific and technical aspects of modern production. Polytechnic skills and abilities include: graphics, computing, measuring, research, diagnostics, design, control and self-control skills, workplace organization (Imashev, 2007a, 2011). The learning of knowledge during the mastering of skills and abilities facilitates students' understanding of the program material, reduces fatigue, teaches to investigate the facts and allows to understand the role of science in labor productivity. This way, teachers are finding opportunities to improve the educational and polytechnic training of students.

A crucial role in our method is played by the system of short case studies, laboratory work front, as well as tasks of high complexity and creative tasks, work on which is mainly carried out during the in-depth study of physics under optional courses (Rieffel & Polak, 2011).

The monitoring of students' work in the classroom has shown that they poorly apply knowledge in solving practical problems, do not know how to apply it in new production facilities. The testing of students confirmed these findings. To get a more objective understanding, a test was carried out among 240

students, which included 84 questions regarding the application and consideration of physical phenomena during work. It turned out that only 38% of students coped with the task. Thus, a definitive conclusion is reached that the involvement polytechnic material is often performed unsatisfactorily. To improve this situation we used the principle of polytechnic education. It is possible to determine the methodology for involving polytechnic material in physics lessons.

Forms of polytechnic knowledge are no different by nature from the knowledge of various sciences, but differ from the latter in its function being aimed at the understanding of bases and techniques of their management (Zhazylbayeva & Salykbayeva, 2014). Therefore, polytechnic knowledge studied at secondary schools is an important means of training students for work in various areas of human activity.

The main polytechnic knowledge and skills evaluation criteria, in our opinion, should be the following: the ability to determine the social significance of subjects; a complete coverage of essential features in the studied areas, the ability to distinguish the essential from the inessential; the ability to analyze the construction and operation of technical facilities; the discovery of the specific manifestations of public knowledge, the ability to generalize; the practical application of knowledge - the ability to operate an object, perform calculations, assembly and disassembly, flaw detection, the transfer of knowledge to practice (from one subject to another). Based on these criteria, we compiled the control tasks.

The learning of knowledge and skills of polytechnic students has formed a broad general technical worldview and thinking, the ability to see and practically use those laws of natural science, which constitute the scientific basis of engineering and technology (Imashev et al., 2014). Therefore, students' learning of polytechnic knowledge and skills should always be based on the knowledge of scientific bases (Atkins & Friedman, 2005).

Thus, the activity of students in mastering polytechnic knowledge and skills will be as follows:

1. Presentation of basic knowledge and skills necessary for learning new material.

2. Performance, at the teacher's request, of independent work with the aim of updating the previously studied concepts.

3. Perception and evaluation of information regarding the studied object.

4. Monitoring of the object's performance during the teacher's demonstration experiment.

5. Learning polytechnic concepts on the basis of substantial generalization: selection of the law underlying the work of the technical object.

6. Application of new knowledge and skills.

7. Ability to compile and elaborate, to find similarities and differences; testing of polytechnic skills; use of instruments and tools, management of technical objects, patterns tracing, production calculations and computations.

The techniques associated with generalization will play a dominant role in the formation of polytechnic knowledge and skills. It should be noted that in the process of generalization, transferred knowledge and concepts are constantly received. It is very important for the quality of mastering the studied material. Generalization and systematization of the polytechnic material were conducted during summarizing lessons and lectures, educational conferences and seminars (Imashev et al., 2014).

Students must clearly understand the role and place of the studied technical objects in production, their functions during their operation and maintenance. They must be able to find substantial connections of the subjects (basic laws), to analyze them, to find the manifestation of a law in other technical facilities, to be able to explain the interaction of components and parts of objects, be able to manage the object, to be able to analyze the new situation and new tasks and relate them to existing knowledge and action methods, that is, to find similarities between the old and new situations, in other words, to be able to make the transfer (Tzoneva, 2000).

Findings

In order to determine the achieved level of skills, 260 written works of experimental classes' students and 250 work of control classes' students were analyzed. The results of these examinations are provided in Table 1 and show that students of experimental classes have reached a higher level of computation, graphical computation and measurement skills (Imashev, 2007b).

Table 1. Polytechnic experimental and control classes students skills formation level

Polytechnic skills	*Experimental classes*				*Control classes*				*% Of correct answers, h*	
	General number of answers, n_e	High	Average	Low	Total number of answers, n_k	High	Average	Low	e	to
Measuring	254	31	53	16	248	17	36	47	84	53
Solution and computing	252	36	45	19	239	20	44	36	81	64
Graphics	260	34	53	13	251	19	42	39	87	61
Experimental	250	28	48	24	242	15	34	51	76	49
Design-Technological	243	20	38	42	235	8	35	57	58	43

It was determined that during the performance of polytechnic tasks, 31% of experimental classes' students formed high level measuring skills, while 53% formed average level skills. It was discovered that the number of students with solution and computational skills of high and medium levels reaches 36% and 45% respectively. During the formation of polytechnic abilities, 34% of the students demonstrated a high level of graphical skills, while the number of students who reached the average level of these skills was 53%.

Many students of experimental classes are able to find devices required to operate the machine, assemble and customize the installation, fix its flaws, are able to apply instruments to take readings of this or that object, draw conclusions and generalizations.

Students of polytechnic control classes were slower to form skills of the middle and high levels. This is due to the fact that the traditional method of forming polytechnic skills in the process of studying physics has no reserves to improve student achievements (Antsyferov, 2002).

The comparative characteristic of quantitative indices of levels of formation of experimental and control classes students' polytechnic training regarding electrodynamics and quantum physics is presented in Table 2.

Table 2. Polytechnic knowledge and skills formation level in physics

Level	*Experimental class*		*Control class*	
	Number of students	%	Number of students	%
High	237	28	109	13
Average	483	57	324	39
Low	127	15	399	48
Total	847	100.0	832	100.0

As is evident from Table 2, the number of the students with a low level of formation of polytechnic knowledge and skills in experimental classes is 3 times less than that of control ones; 85% of students of experimental classes and 52% of control classes students showed average and high levels of skills.

The discovered levels of formation of knowledge and abilities show that there was an improvement of experimental classes' students' knowledge of at all three levels in comparison with the results of the summative experiment.

Discussion and Conclusions

The analysis of experimental works, conducted at the end of the 2013/2014 academic years, aimed at assessing the students' polytechnic knowledge and skills formation level, showed that the students' knowledge has improved at all three levels, compared to the results of the summative experiment. This data indicates that the level of development of polytechnic knowledge and skills in the experimental classes increased on average by 16% when compared to the control classes. The results obtained in the experimental classes, in comparison with the results of the control classes, prove that the application of the formation and development of polytechnic knowledge and skills of students during the study of a physics course technique, developed by us, leads to a significant extension and broadening of knowledge and skills of physics course students.

Based on the students' responses, the authors established that the students have acquired skills of describing physical phenomena and patterns in modern equipment, performing laboratory work, solving polytechnic tasks.

According to N.N. Tulkibayeva (1995) attention has to be simultaneously paid to the study of physical theories and to the formation on this basis of generalized polytechnic knowledge and abilities. According to it, there is a tendency of transition from the acquaintance of students with the application of the studied physical phenomena and regularities, outlined during the last decade in industrial and agricultural production, to the acquaintance with the main areas of scientific and technical process and physical bases of these areas.

Thus, polytechnic skills can be considered as generalized ways of targeted application of knowledge in typical conditions of practical activities. They add up to a certain level of knowledge and are based on specific methods of program material learning on the one hand and on the production and labor operations, the synthesis of which leads to the understanding of generalized principles of application of methods of science in practice, on the other hand.

Implications and Recommendations

The state of the problem of forming polytechnic knowledge and abilities under modern conditions is studied. The possibility of reinforcing a physics course polytechnic orientation of studying in accordance with the requirements of industrial and innovative development at the present stage is proved. Criteria of formation of polytechnic knowledge and abilities in the course of studying physics are revealed and used. Based on these criteria, three levels of knowledge formation are established and their characteristics are provided. During a pedagogical experiment, it is proved that the use of the developed methods of formation of knowledge and abilities promotes the reinforcing of a polytechnic orientation of studying of a physics course, allows to reach a higher standard of knowledge of scientific bases of modern production. It is established that the reached level of abilities of experimental classes' students, the extension and deepening of their knowledge, is higher.

Thus, polytechnic education of students develops in them a conscious, creative approach to the activity in the field of equipment and technology, enriches the area of their public relations and provides norms of conscious behavior, as well as a wide basis for the choice of profession, associated with equipment. All this helps define one's place in society according to one's abilities, which is a condition for a further formation of a comprehensively developed individual.

In scientific and pedagogical literature, some classification systems of polytechnic knowledge and abilities have been defined, but the complexity of the problem is defined mainly by the fact that many authors quite often use various specialized criteria as a classification basis. Considering modern requirements to schools, the contents and organization of labor polytechnic training, further development of the contents and techniques of polytechnic education has to follow, in our opinion, the suit of emphasizing and studying the general bases of modern production.

Disclosure statement

No potential conflict of interest was reported by the authors.

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