UDC 53

Students' Training in Doing Laboratory Works on Physics

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Abstract

Based on the analysis of advantages and disadvantages of laboratory training methods on physics, personal practical experience, the article describes and justifies intensification of students' training at engineering university in physics laboratory in terms of problem-based approach. The feasibility of specially selected and developed tasks and problems is shown at the specified stages, interactive models, which improves the learning outcomes.

Key words: laboratory work on physics, methods of students' training, interactive models, objectives and tasks.

The general physics course is a basic discipline for future specialists of engineering profiles, without which it is impossible to be a competent engineer who meets modern requirements. Besides, physics is a subject with maximal capacities of developing not only professional, but also personal characteristics of future engineers and, what is more, scientific thinking, which is universal, tightly associated with creativity, and provides reliability of results in any sphere. Therefore, this subject should be paid special attention in engineering students' training.

When training physics at university the following forms are used: lecture, seminar, practical class, laboratory work, student independent work. In addition, physics learning is closely connected with physics experiment both for demonstration and laboratory work. A special place in Bachelor, Specialist and Master training is given to the laboratory physics practice. Physics practice is an integral part of physics course and plays a key role in teaching students the experimental bases of physical laws, phenomena, and processes, developing self-study and experimental skills.

Among the principle teaching goals of laboratory work are:

- observation, experimental evidence, and verification of theory (laws, relations);
- determination of physical constants, substance characteristics and processes;
- study in structure and operation of physical facilities.

The key role of experiment in physics teaching methods has been proved by numerous both domestic and foreign researchers [1-4].

The lab work develops experimental skills and abilities, effectively solves the problem of integrating knowledge, universal intellectual and practical skills and abilities, forms students' professional and personal qualities such as activity, independence, tidiness, analytical thinking, transfer of acquired skills into new situations, etc.

The most common method of laboratory work on physics is students' regular performance of lab works. Groups consisting of, as a rule, two students perform lab works of different content, but of the same theme according to teacher's schedule. However, in this case there appear some challenges, such as: the themes of lab works do not usually coincide with previous topics studied by the students; joint work performance makes monitoring of each student's independent work difficult.

Among the most essential disadvantages of first-year students' preparation for efficient work in physics laboratory are insufficient level of their experimental skills and abilities. Among the reasons is an imitating character of making teaching experiment in physics class at school consisting in measurements and calculations using formulas and detailed descriptions. A formal approach is often used in lab work performance at university as well, when the focus is made on teacher's requirement to submit a carefully designed report on lab work in time presenting the results similar to those calculated by the teacher.

As practice shows, a traditional method of lab classes at university using laboratory operation manuals results in the situation when a student strictly following the manual can perform a lab work without understanding either the essence of performed experiment or physics in general. The challenges mentioned above are exacerbated by a current sharp reduction of class room hours of learning physics at university including lab work hours.

The solution is possible in searching for and practical introduction of new approaches to organization and delivery of general physics labs.

For example, Yu.F. Sviredenko, V.P. Kuntsov, N.N. Martynich have applied a problem-based method in lab classes. In this case they do some preparatory work with students giving them the rules of team thinking work, split the students into subgroups for initial problem discussion, and involve all students into discussion of the problem [5].

When arranging such physics lab class, students are given only problems, whereas the ways of their solutions they find independently passing all research stages – unit assembly, measurement, result processing, etc. However, this method can be used in this form only in independent work of high-achieving students, while the elements of this method are to be taught for all students. For example, the tasks can be as follows: to determine possible ways of indirect measuring some magnitude, define the needed devices measuring techniques independently.

As an essential drawback of teaching physics at university the researchers have noted the inconsistency of lectures, classes, and lab works [6]. V.V. Svetozarov, Yu.V. Svetozarov proposed the technique which eliminated this drawback. It was based on the so-called complex class, at which study of theory is combined with lab works as a single cycle. To deliver such classes, the authors suggested using hours of seminars and lab works together, while lectures were to be delivered as usual. At the complex class, theory is taught in the form of reviewing, monitoring, and enhancing knowledge. Experiment is included in the class to put forward a hypothesis, observe physical phenomena and processes, and support laws. It is made in combination with theory and solution of physical problems. With all obvious advantages of this method, there are some disadvantages, among which is unsuitability of most lab rooms for complex classes. Among the drawbacks the authors themselves noted: the lack of seating capacity, low monitoring of students' readiness for classes, need for joint work at one unit that results in the situation when a more active student reduces other students' initiative [6].

The combination of lab work and classes is proposed as a basis for lab practice by V.S. Zvonov, A.S. Polyakov, V.N. Skrebov, A.I. Trubilko. These combined classes are delivered after a lecture course on definite physics section. The length of this class is six hours, therefore, students have an opportunity to learn independently, as there is no time lag between giving, performance, and control of the task, students' work become individualized, there is a shift from instructive teaching to activity-based approach [7].

We think, special attention should be paid to research in different aspects of using problems at lab works [7, 8, 9]. For example, K.P. Kortnev and N.N. Shusharina propose a method, in which in addition to theory study and lab work instruction a student is to solve several individually selected problems at the preparatory stage. The problems are of research character and selected with the aim to prepare a student for solving experimental problem related to this lab work.

In authors' opinion, this method allows the reduction of existing gap between problem solution and lab work as well as development of students' research skills. Before the lab work, a student is suggested to solve three problems:

- the first problem is given with relatively standard condition, introducing a concept of object, its properties, i.e. a model that is further used in the lab work;
- the second problem is of higher complexity level and it occupies an intermediate position between training and creative problems;
- the third problem is the most complicated as it is of creative character. Its solution smoothly progresses to experimental research made within the lab work [9].

Hence, modeling physical processes, which is performed in solving problems, a student goes to experimental research, where he/she practically checks the validity of modelled concepts and reveals the relations among physical phenomena, magnitudes, and parameters. However, solution of theoretical problems in the course of lab work takes time scheduled for experimental work, which is unacceptable due to the lack of class hours assigned for lab works.

One can identify the most common framework of lab works on physics consisting of four stages: preliminary preparation; making experiment; brief report including experimental result processing, error estimation, records of results and conclusions; submission of lab work.

Ye.V. Yermakova developed the method of lab work performance on general physics based on a problem including support problem as a means of enhancing knowledge, its choice, place, and function at the lab works. In addition, the structure of methodical description is developed for the lab works using the problems [10].

The support problems are problems focused on understanding the essence of lab work close as much as possible to the real practice at lab classes. These are problems, the solution of which reveals some physical meaning of the objects, phenomena (processes) of lab work, their interconnection and interaction.

Taking into account that students' lab activity consists of four main actions, the support problems can be divided into the following basic groups: tasks of preliminary preparation for a lab work, problems for making experiment; task of processing results; control problems and self-control problems [9].

Among the tasks of preliminary preparation: problems showing an approach to a study phenomenon, helping to understand the study regulations; problems of reproduction or determination of calculation formula; problems explaining the phenomena and processes occurred in the study. It means that qualitative or simple calculation problems do not take much time at the classes and they can be solved by a student independently at home when preparing for classes.

Based on the methodical literature, our own research and working experience, it is possible to state a noticeable increase in students' learning outcomes on physics lab work based on the system use of problem-based approach to training and performance of lab works. This work is to start from the introductory lesson. Considering the elements of the error theory, the students are proposed specially developed tasks on mastering methods of absolute error calculation, correct answer record, chart reading [11]. At the next classes there is a measurement practical course where the whole set of practical skills is developed

ENGINEERING EDUCATION 22'2017

and students are suggested to solve problems of different complexity. For example, determine the body density using a caliper and scales (students are given a body of regular geometrical forms from different materials). The support problems of preliminary preparation for lab works as well as control and self-control problems [11] are to be solved by the students independently at the stage of work preparation and submission, which allows managing class time effectively.

Let us give examples of tasks and problems used for preparation, performance, and submission of lab work "Determination of air heat capacity relations using Clement-Desormes method".

At the preparatory stage:

1. What is adiabatic process? Give examples.

2. What is a degree of freedom? What are they? What does the number of gas molecules depend on?

3. Write down and comment upon Poisson equation. How is adiabatic index determined in terms of heat capacity? In terms of the number of freedom degrees? In this work?

4. What does Clement-Desormes method consist of? What is its essence?

5. What is air? What should air adiabatic index be in standard conditions?

Problems for making experiment:

1. What impact does the balloon volume have on adiabatic index?

2. Why is not h1 set just after pumping air in the balloon?

At the result possessing stage:

1. What are the reasons for deviation of an experimental value of adiabatic index from a theoretical one? What is physical mechanism of these reasons?

Control and self-control problems:

1. What should the γ relation of argon, nitrogen, carbon based the classical theory?

2. Calculate: specific heat capacities of gas mixtures consisting of 10 g of hydrogen and 14 g nitrogen; adiabatic index of gas mixture containing 8 g of helium and 2 g of hydrogen.

3. In standard conditions some gas has specific volume 0,7m^3/kg. Determine specific heat capacities of this gas. What is this gas?

Computers also give ample opportunities in making lab experiment.

From personal working experience we can state that in order to get better learning outcomes, a practical lab work on definite sections of physics is preferably added with computer modelling of those lab works, which performance is either hard in real time or requires modelling for better understanding of physical processes (electromagnetism, concepts of quantum, atomic, and nuclear physics). It should be underlined that they should be only added but not replaced by modelling. Though there are some investigations, where higher students learning outcomes are presented with the use of computer modelling as compared with the students using only lab equipment to solve the same experimental problems [12], one may not refuse the true experiment in favor of virtual one. Students have to work with actual physical devices, assemble experimental units, and use measuring equipment.

It is useful to add interactive computer models to the lab work as such models often allow adequate visibility of complicated physical phenomena and processes, which is impossible when using standard lab equipment.

The most useful are dynamic interactive models, as they support most of essential research stages. They can be used to [13]:

- observe, classify, and generalize the facts including similarities and regularities of the results;
- interpret data;
- explain the observed phenomena and put forward hypothesis;
- design a model experiment to verify hypothesis and make it;
- make conclusion based on performed experiment.

It is possible to highlight dynamic interactive models intended for demonstration, research, design, interactive training units, and interactive problems. The whole range of interactive models in all basic sections of physics is included in interactive source book with multimedia support of physics classes [14] that is widely used by students at all forms of learning (lectures, practical classes, and lab works) and upper class students of secondary school.

In addition, electronic teaching package "Lab work on physics" was developed and successfully used [11]. The package includes two electronic manuals, where there are descriptions of lab works and guidance of their performance in all basic sections of general physics course, which are used at Yurga Technological Institute, TPU. Every lab work consists of tasks and problems divided into units: Unit I. Questions and support problems at the preparatory stage. Unit II. Questions and support problems at the stage of making experiment and result processing. Unit III. Questions and problems for control and self-control.

Besides, the package contains: lectures on the entire physics course; guidebook; interactive multimedia support materials of lab works (interactive figures, models, lab stands); virtual lab works to monitor and develop the basic experimental skills and abilities.

All teaching materials of this package were thoroughly reviewed: they include context menu, active links in the content and integrated into electronic shells. The following software was used: iSpring 7, Adobe Acrobat XI Pro, FlippingBook Publisher Professional, AutoPlay Menu Builder, etc. The given technical solutions provide usability in classroom and at home, sufficiently save time to follow the needed link, find necessary information, print any part of resource and use it in paper form. To use the package resources, interactive models in particular, it is not necessary to connect a computer to Internet, which is very important.

The described method of preparing and doing lab works is a part of students' training in physics based on forward-looking independent work, including the method of students' active cognitive activity at the physics lectures [15], method of teaching students to solve problems on physics in terms of activity-based approach [16, 17].

To assess the efficiency of lab works, the students of experimental (48 students) and reference group (60 students) were distributed into three levels of knowledge and skills to design and make experiment and process the results. For this purpose, we used tests and interview, for which teachers not teaching these groups were involved. To process the results of experiment, the criterion application method developed by K. Pearson was used χ^2 [18]. At the initial stage $\chi^2_{н}$ = 0,244. At the significance level α=0,05 the critical value of freedom degrees L-1=2 is equal to $\chi^2_{кр}$ = 5,99. It means that students have the same level of knowledge and skills at the beginning of experiment (Table 1).

At the final stage (at the end of the second term of learning physics) students of experimental groups showed higher results $\chi^2_{к}$ = 7,81 at $\chi^2_{кр}$ = 5,99 that makes us accept the method described above as more effective as compared with the traditional one.

Table1. Distribution of students in reference and experimental groups in terms of knowledge and skill levels

Levels	The number of students at the initial stage		The number of students at the final stage	
	Reference group	Experimental group	Reference group	Experimental group
1	16	12	15	4
2	31	27	33	25
3	13	9	12	19

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Analyzing Employment of HEI Graduates According to the Enlarged Groups of Specialties

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Abstract
The article analyses indicators of Saint Petersburg HEIs graduates' employment according to the enlarged groups of specialties. The research allows determining groups of specialties with highest graduates' employment rate, as well as to allocate HEIs according to their graduates' employment rate within each enlarged group of specialties.

Key words: HEI graduates, employment rate, average salary, enlarged groups of specialties.

Methods for analysis of HEI graduates' employment

The analysis of young specialists' – HEI graduates' employment is topical and particularly essential both for HEIs and for the whole country. Today, the most complete and trustworthy source for HEI graduates' employment evaluation in Russian Federation is the Portal for monitoring graduates' employment (based on the statistics of the Pension Fund of the Russian Federation) [1]. The key indicators for evaluating young specialists' employment on the Portal are the percent of employed graduates and their average salary. Portal's navigation system allows analyzing data by the constituent entities of the Russian Federation, by educational organizations, by specialties and majors.

The data for this monitoring is provided by the Pension Fund of the Russian Federation, the Federal Service for Supervision in Education and Science and educational organizations. The result of the third monitoring of graduates' employment is the processed data on more than 1.267.000 graduates of the year 2015 determined by their employment data from 2016 [2]. Thus, the information on graduates' employment is provided with free access with a 2-year lag: the first year is dedicated to the monitoring itself – the data on pension contributions from graduates' salaries is analyzed; the second year is for data processing and presentation on the Portal.

Based on the data from the Portal for monitoring of graduates' employment Saint Petersburg Electrotechnical University "LETI" has initiated a comparative research on the employment of young specialists of Saint Petersburg on a number of the most widespread enlarged groups of specialties. In light of this, the research group has studied data on the employment of graduates of 15 groups of specialties from 21 university of Saint Petersburg. Criteria for choosing the most widespread enlarged groups of specialties of Saint Petersburg to be included in the study were the following: at least 5 universities provide majors in this enlarged group of specialties, and each HEI provides at least 25 graduates within this group.

Table 1 provides information on the enlarged groups of specialties included in the study: codes and titles of the enlarged groups, number of Saint Petersburg HEIs that had at least 25 graduates of these groups of specialties in 2015.

Codes listed in the table correspond to the approved list of specialties and majors of the higher education [3].