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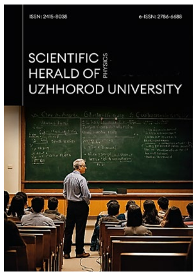

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Methods of professionally-oriented teaching of physics to students of technical universities

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Abstract

Relevance. The study of technical, and especially physical, education at the secondary and higher education levels in recent years has focused more on the exploration of concepts or understanding than on the development of skills and values. The least attention was paid to the development of values. Teaching physics in lectures often emphasises concepts and their interrelation, while the laboratory class also focuses on the development of laboratory skills.

Purpose. The purpose of the study is to investigate the methods of professionally-oriented teaching of physics to students of technical universities.

Methodology. Systematic review can be explained as a research method and process for identifying and critically evaluating relevant studies, and for collecting and analysing data from these studies. When promoting physics among the

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population and encouraging students to pursue a career in physics, emphasis is usually placed on developing the ability to solve problems in physics. In the review of the value of the physics diploma, graduates of the technical university emphasised the importance of skills in their profession.

Results. It is assumed that with the help of an interactive way of teaching physics, it would be possible to eliminate students' misconceptions, reduce the dropout rate of first-year students, and also increase the level of students' knowledge in introductory general physics courses, mainly in the field of mechanics.

Conclusions. The concept of "knowledge in motion" combined with theories in the workplace can offer a useful conceptual union for studying the nature of professional knowledge, which is taught to students of technical specialities after vocational education and training courses. This suggests that professional knowledge, rather than as a dichotomy, is perhaps more correctly viewed as distributed and networked.

Keywords: physics; technical education; methods of teaching physics; features of technical education; students of technical specialities.

Introduction

The study of technical, and especially physical, education at the secondary and higher education levels in recent years has focused more on the exploration of concepts or understanding than on the development of skills and values. The least attention was paid to the development of values. Teaching physics in lectures often emphasises concepts and their interrelation, while the laboratory class also focuses on the development of laboratory skills. However, in the workplace, the employability of physics graduates seems to depend more on general skills and values that can be transferred to many areas of research, work and life in general [1]. For the general population and the vast majority of students who will not study physics, teaching physics to improve scientific literacy and scientific culture in a given society is a priority in physics education. UNESCO is leading international efforts to improve scientific literacy, especially in developing countries, implementing the crucial role of science and technology in national development [2].

Recently, international attention has been paid to education for sustainable development, and it has also been declared the United Nations Decade for Sustainable Development. Like scientific literacy, sustainable development is filled not only with concepts, but also with skills and values, such as human development, moral, cultural, and gender sensitivity, participatory democracy, cooperation, unity, and peace [3].

This paper uses the conceptual framework of knowledge in motion and concepts extracted from the theory of on-the-job training to report on the experience of continuous professional development of teachers of vocational schools. It explores how teachers of vocational schools can maintain and update their professional knowledge and use it to ensure more effective and relevant training of students. It is used to address some of the current disputes about the nature of professional knowledge that is taught in technical colleges to students studying in craft, professional and vocational areas of study. The research ideas presented here have been stimulated by recent policy initiatives that have focused on vocational training and the training of teachers of technical specialities. These initiatives have exacerbated ongoing discussions and concerns about the quality, nature and purpose of vocational education and training. With regard to curriculum issues, it suggests that the reorientation of vocational education and training over the past 30 years towards the skills and competencies has emptied the content of knowledge from vocational training programmes [4].

This paper examines selected studies and prospects for the development of skills and values, models and trends in the teaching of physics, and also suggests areas that should be considered by the community engaged in physical education. The skills required to study physics can be categorised as thinking skills, including scientific process skills, professional skills, communication skills, and interpersonal communication skills. For example, the section "Development of values" is devoted to the attitude to science and its image for students [5].

There is a similar position that vocational education and training has been reduced to the acquisition of skills. No less worrying is the fact that the intended purpose of professional qualifications falls into three groups: the development of knowledge and skills in the workplace; the development of general and transferable skills, such as employment opportunities and personal learning skills; the development of subject knowledge and theory. In the study by Batmaker on interested parties from award-giving bodies that develop professional qualifications, and government departments that set policies for vocational training programmes, it was found that more attention is paid to employability skills, rather than specialised professional knowledge. These contradictory ideas about the types of knowledge that should be included in vocational training programmes emphasise some differences over the definitions of professional knowledge [6]. The purpose of the study is to investigate the methods of professionally-oriented teaching of physics to students of technical universities.

Materials and Methods

Systematic review can be explained as a research method and process for identifying and critically evaluating relevant studies, and for collecting and analysing data from these studies. The purpose of a systematic review is to identify all empirical data that meet pre-defined inclusion criteria to answer a specific research question or hypothesis. By using explicit and systematic methods when reviewing papers and all available evidence, bias can be minimised, thereby providing reliable results based on which conclusions can be drawn and decisions can be made.

Meta-analysis is a statistical method of combining the results of different studies for weighing and comparing, and for identifying patterns, disagreements, or interrelations that appear in the context of several studies on the same topic. In the meta-analytical approach, each primary study is abstracted and encoded, and the results are subsequently converted into a common metric to calculate the overall effect value. However, to be able to perform a meta-analysis, the included studies must have common statistical indicators (effect size) to compare the results. Therefore, it is difficult to conduct a meta-analysis of studies using various methodological approaches.

After reviewing the literature and selecting the final sample, it is important to think about how the papers will be used for conducting the appropriate analysis. That is, after selecting the final sample, the standardised means of abstracting the relevant information from each paper should be used. The extracted data can have the form of descriptive information, such as authors, years of publication, topic or type of research, or in the form of effects and results. It can also take the form of a conceptualisation of a certain idea or a theoretical position. It is important to note that this should be done in accordance with the purpose and research question of a particular review, and the form may be different. At this stage, it is necessary to consider the opportunity of training the reviewers to avoid any differences in encoding and abstraction (if there is more than one), and to closely monitor the abstraction of data during the review process to ensure quality and reliability. Commonly, if the purpose is a publication in an academic journal, this requires a detailed description of the process or an assessment of reliability between reviewers. Sometimes it is easy to do this if the information of interest is, for example, the general body, the size of the effect, or the sample size. However, it becomes more difficult when the information of interest is topics from literature, perspectives or historical chronology. This would require a detailed description of the process or an indicator of reliability between reviewers.

Results and Discussion

When promoting physics among the population and encouraging students to pursue a career in physics, emphasis is usually placed on developing the ability to solve problems in physics. In the review of the value of the physics diploma, graduates of the technical university emphasised the importance of the following skills in their profession:

1. Professional proficiency, mathematics, and other technical skills.
2. Problem-solving skills – allow working with various advanced technologies.
3. Mathematical skills applied to physical systems.
4. Analysis and modelling of the physical process.
5. Data collection, creation, and testing of models and forecasts.
6. Experimental, computational, theoretical skills – applicable to a wide range of problems.
7. Scientific method of thinking that is applicable in all spheres of life.
8. Ability to quickly and effectively learn new information.
9. Ability to logically and systematically follow a thought.
10. Analytical skills, accurate thinking, clarity of thought.
11. Decision-making based on logical data.
12. Writing, speaking, thinking in a logical, predictable, and consistent way is appreciated in the work.
13. To learn new things on your own.
14. Skills of how to learn, identify problems, plan strategically, implement and communicate solutions; creative thinking skills.
15. Self-study skills and time management.

The principles of sustainable development are values such as cultural sensitivity. Students can bring physics-related items to the classroom, such as local toys and musical instruments. If necessary, students can engage in physical cultural practices (scientific and non-scientific), for example, fishing on a full moon. Moral sensitivity can be demonstrated by discussing cultural values compared to scientific values, for example, the influence of friendship on objectivity.

Community-based physics education, an approach to involving the class in the community, considers the needs of the community related to physics, and uses physics-based resources. Self-determination and participatory democracy are developed in physics lessons with group classes, experiments and discussions, the inclusion of a research plan or projects, and the use of self-learning modules and the Internet [7].

The principle of social justice can be implemented through high-quality teaching of physics to the poor in public schools, especially in remote ones. These schools should be provided with master teachers and supplied with the same educational materials as in urban schools. In any classroom, students who are at risk of dropping out must be identified and provided with a correction curriculum and advice. Information programmes in physics, such as public projects, can be developed for students who have dropped out of school, so that they eventually return to the formal stream [8].

To promote peace, order and unity, the physics class can conduct joint training in group activities and experiments, and the climate in the classroom promotes learning. The values of responsibility, openness and respect for others can develop among students when they work in groups. Global connections or cooperation in teaching physics can take the form of cooperation with scientists through e-mail, discussions in electronic groups, general laboratory experiments and video conferences with classes in other countries, and international competitions, such as the International Physics Olympiad. Students from all countries fully agree that science and technology are important for society and provide great opportunities for future generations; in most countries, students think that science and technology make work more interesting; and most students (mostly boys) think that the benefits of science are greater than its potential harm. In addition, the opposition can be seen in the opposition of professional knowledge to academic knowledge, which overshadows professional education and training and clouds discussions about professional knowledge. It is assumed that vocational education "... is regularly positioned as a second chance, and often a second choice, an alternative to "academic education" based on general subjects, and when planning curricula and policies, vocational education and training was necessary to ensure their equivalence with the academic certificate of secondary education and A-level qualifications [9-11].

Researchers also argue that vocational education and training has historically had a lower status than academic general education. In response, successive пovernments have made attempts to achieve parity of respect between professional and academic qualifications, but without much success. The dichotomy of professional and academic knowledge dates back to medieval universities, where a distinction was made between humanities and practically useful knowledge. This is described as a fault line, which is still evident today, when only seven humanities were taught at universities, and not seven mechanical arts, such as fabric production, shipbuilding, navigation, agriculture, hunting, healing, and acting.

To challenge the dichotomy and assumptions about parity and to offer an alternative approach to understanding professional knowledge, this paper uses two theoretical standpoints to understand how teachers can master professional knowledge, and how the experience of continuous professional development can be used to facilitate the transfer of professional knowledge to formal classes in technical higher educational institutions. Firstly, the theory of on-the-job training distinguishes between academic and professional knowledge. Within the framework of working approaches, there are debates arguing that professional knowledge is generally tacit, informal, and largely uncodified. In this context, a perspective is proposed that gives priority to implicit knowledge and recognises that people master different types of knowledge in different ways. In this regard, a special problem arises, which is that if professional knowledge is implicit and, therefore, problematic for coding, how is it transmitted in different contexts. This, in turn, indicates that for both curriculum developers and teachers of vocational schools, both the identification of professional knowledge and its transformation into portable forms, such as textbooks used for more general academic knowledge, present a problem. Thus, the second conceptual lens is used to concretise such transfer processes. Using the concept of knowledge in motion, it is argued here that professional knowledge moves in different contexts through networks, and it is the actions of professional teachers through their continuous professional development that allow this process.

Implicit professional knowledge is often contrasted with codified propositional knowledge, and researchers distinguish between conditional and implicit as "innovation", decontextualised and codified as "known" [12; 13]. However, the problem in this binary system is that, as it is recognised, the boundary between them is not clearly defined, and knowledge does not easily slip into one or another of these categories. All knowledge is a permutation of both implicit, uncodified, and explicit, codified knowledge, and that knowledge is the action of their integration. Another way to demonstrate this slipperiness is that it is possible to make certain aspects of implicit knowledge explicit and encode it. An analysis of this leads to the conclusion that there are three different codification possibilities: one that can be relatively easily codified, one that cannot be codified because it is not available, and, in between, semi-codified knowledge, which is possible but problematic to codify.

Codified knowledge is defined here as the knowledge contained in the curriculum, in courses, assessment and accompanying textbooks, and in other educational and training materials. However, practices, customs, approaches, new ideas and ways of working in the workplace, which should also be reflected in vocational training programmes, are determined by their resistance to codification. However, the practice of codifying professional knowledge is often seen as hassle-free and illustrated. The systematised knowledge in printed collections and plans allowed separating thinking from execution in post-industrial workplaces. The criticism of the separation of thinking and actions emphasises the assumption that working methods and professional knowledge can be systematised and transferred to classes using artefacts without problems and by third parties removed from the direct process of teaching and learning [14].

This creates a problem, since implicit or uncodified knowledge makes up a significant part of the knowledge that is exchanged, used, and applied in professional institutions. It develops through practice. Contrasting systematised and implicit knowledge, implicit knowledge is described as something that we know, but cannot say. Scientists argue that implicit knowledge, because it resists codification, is becoming the most important form of knowledge in learning organisations, and that attempts to capture informal knowledge generated by informal methods are becoming increasingly strategic for the production of new knowledge in various ways. Therefore, it is difficult to imagine how professional knowledge is transferred for use in the information space classes [15; 16].

Between them lies knowledge that is partially codified. The purpose of this level of codification is to ensure the exchange of knowledge within a particular profession or industry. Unlike the systematised knowledge found in classrooms, artefacts, processes, and mechanisms used to collect practical knowledge are not produced or organised specifically for the formal purposes of the curriculum, but for use by those who work in a given profession or industry [17]. This is similar to product knowledge, described as information about new cars is encoded in manuals and brochures stored in the sales manager's office and on the internet for use with sales managers and customers. In the study of Japanese corporations, semi-codified knowledge is conceptualised as common between "insiders". Researchers describe this centrally positioned form of knowledge as vague, fuzzy, and semi-codified, and define it as institution-based knowledge that is provided only to trustworthy insiders. As for the implicit professional knowledge that needs to be recorded for transportation to classrooms, it can also be considered as a trade secret, which is most easily accessed by insiders or professional experts [18; 19].

The initial conceptualisation of implicit knowledge is also useful in exploring where knowledge is said to reside. One interpretation considers implicit knowledge as personal knowledge that is inside a person, while an alternative interpretation considers it as part of a community of practitioners. It is claimed that they consider tacit knowledge as inherent in man. The tacit knowledge is discussed from the standpoint of personal knowledge. However, alternative applications treat tacit knowledge as a common effort. The problem is emphasised of considering implicit knowledge as inherent in individuals and, based on the study, it is suggested to considering it as part of a community of practitioners. In the study on how communities of practitioners develop outside of the formal continuing professional development programme for adults and community teachers, the tacit knowledge is considered as inherent in communities of practitioners, and not to the individual. What is important in these two studies is that they emphasise how it is possible to understand how knowledge can be transferred both in practice and in some cases when it crosses organisational boundaries and contexts [20-22].

These epistemological discussions about the nature of professional knowledge, although they are a deeper understanding, do not provide much in terms of explaining the ways in which professional knowledge can be transferred from the profession to the classrooms. Using the concept of knowledge in motion and considering its development and dissemination as a network effect, the processes involved are clarified. In the empirical study of physics students and undergraduate programme managers, knowledge is considered as a relational network. Researchers believe that learning and knowledge arise through the materialisation of networks and network practices. In their argumentation, they resolutely depart from both individualistic approaches and from a limited context. They study the experience and development of students through the theoretical study of space, time and the curriculum, using it to demonstrate how activities are organised in space and time and how space and time are produced in social practices [23; 24]. This concept of space-time can be understood by the example about how physics students living in different parts of the United States enter into social relations with each other through a standardised test programme and textbooks [25]. This spatio-temporal compression is explained as the articulation of global processes in local conditions, through which students can contact others at different times and in different conditions. Thus, knowledge can be considered as a network effect that organises space-time so that it is possible to simultaneously interact with people and artefacts in the immediate environment, and with those who are at a distance in space and time. However, in contrast to the theory of learning in the workplace, which considers knowledge as implicit and situational, knowledge is organised into disciplines. Nevertheless, network analysis is equally applicable to professional knowledge. By studying network structures and multiplicity, it is possible to analyse how the practice of knowledge goes beyond contexts and boundaries, which allows studying how teachers transmit professional knowledge [26].

An important sign of professional basic knowledge is that it has a high level of proficiency. Researchers who, when discussing the needs of professional development of teachers of vocational schools, state that "... practitioners with significant work experience can see that this knowledge is losing relevance in rapidly changing technologies and operating systems". Work practice and new trends are developing, which soon ensures that even a high level of professional knowledge can quickly become outdated. In addition, the researchers suggest that vocational education and training are only part of the issue. It is subject to various understandings and is marked by time shifts. The workforce overcomes time and space constraints. This second point is also emphasised by researchers who, discussing the professional development needs of Australian teachers of vocational schools, suggest that partly temporary factors in the workplace can create both opportunities and obstacles to learning. Similarly, in the review of the teaching and training of vocational and technical education for adults, it is argued that students of vocational educational institutions who find themselves in the classes of teachers of vocational educational institutions are distributed by profession in different workplaces and, thus, reflect changing spatial and temporal patterns of work. Network theories also use this concept of temporality, and the study of Nespore theoretically links teaching with disciplines through spatio-temporal and spatial practices [27-29].

The currency and temporality ensure the fluidity and permanence of knowledge. This then reinforces the conceptualisation of knowledge as part of a network that is constantly in motion. Then it can be explained as if the planned festival did not take place or the newspaper was not printed today, the grouping would be lost. A festival or a newspaper, in this case, is not only a building or a venue, or some other specific artefact, or a special context, but a collection of things that need movement, distribution, and connections to ensure its continuation. People need labs, laptops, computers, equations, and colleagues to be "physicists"; suits, offices, memoranda, and organisations to be "managers" (and the whole path leading people to configurations with these elements is key here, not just ownership of them). If a physics student or a manager to be left on a desert island without their tools and colleagues, and questions about what they "know" and in what sense they have learned become controversial [30].

This highlights where workplace theories and work complement each other, where workplace learning theory considers knowledge as being in the materially limited contexts of specific workplaces, shared in communities, network theory considers it as being in the volatile and ephemeral networks of both people and inanimate objects, not always limited by the context. Thus, professional knowledge cannot be analysed as a separate unit, but must be studied as it works and interacts with other parts of the network, for example, where teachers and industry experts come together. It should also include human and non-human objects in the network. Along with individuals and groups, it should recognise tools and artefacts, contexts and places in which professional knowledge is exchanged and disseminated. For example, the system of secondary and higher education is mainly a state with a regulatory budget and has undergone several changes since 1989. Currently, each school can develop certain educational programmes within this structure. To be more specific, teachers can decide how many lessons they would like to devote to each subject in each academic year [31].

Most secondary schools have decided to support the study of foreign languages by teaching them five times a week plus two lessons dedicated to the development of communication. However, at the same time, they reduced the number of physics and mathematics lessons per week. Gradually, mathematics is usually taught three or four times a week, physics once a week, and only during the first two years of the curriculum plus laboratory work are reduced or even cancelled in some schools. Students are less interested in studying mathematics and physics, because they find them difficult to study, understand, and pass final exams [32; 33]. As a result, most students entering technical universities have only theoretical knowledge about physical phenomena, a few biases and misconceptions, and only a few of them passed the final exam in physics, which means that most of them studied physics for the last time in the second year of study. The insufficient level of knowledge in physics was proved by several repeated studies. Therefore, it was decided to focus this study on the problems of physical education to solve the main task – to retain students who would be interested in the science, technology, training, even if their knowledge of physics is unsatisfactory, and to help them overcome this gap and continue their education, without dropping it during the first semester [34].

The research has shown that students have difficulty understanding the basic concepts of mechanics at the initial stage of their studies at both universities. Knowledge of the relationship between concepts, physical principles, and the real world is also often weak. The study came to the conclusion that: this result does not depend on the instructor and the curriculum; common sense ideas about motion and force are incompatible with Newtonian concepts in many respects; ordinary physics course does not change much in these beliefs. The authors further note that the first impression of most physics teachers is that the questions are too trivial. It is shocking when they discover how poorly their own students are coping with this [35].

According to the study, 60% of the test, for empirical reasons, is the minimum threshold for the student to continue to effectively understand Newtonian mechanics. Below this threshold, the student's understanding of Newtonian concepts is not enough for effective problem-solving. Otherwise, the student would not be able to overcome the difficulties that caused them to have a wrong idea, and therefore the student will learn physics by heart. 80-85% of the test represents the level of mastery when the student thinks in terms of intentions and Newtonian physics. According to the authors, such a result does not depend on the teacher, the country, or the school [36].

To achieve better results with the current quality of students, it seems necessary to use more effective interactive methods and pay more attention to an active and creative, more conceptual approach to quickly improve the qualifications of students at the beginning of their studies, their research. Problem-based learning, project-based learning, video-based tasks, Internet-based learning, interactive methods, the application of conceptual questions, an introductory programme in physics based on models and other query-based learning methods improve the cognitive skills of higher-order and students better than those who attend traditional lectures and laboratory classes [37]. According to the authors of this study, video analysis and modelling of problem problems using interactive software are the methods that significantly help to form conceptual thinking and at the same time to eliminate misconceptions, develop manual skills and intellectual abilities of students [9].

Conclusions

It is recommended to shift the focus on skills and values in teaching physics, to supplement them with more detailed research on the development of skills and values. The transferability of skills and values in many areas of life and their crucial importance for scientific literacy and sustainable development in rich and poor countries cannot be overestimated. Some skills, such as understanding physics texts, decision-making skills, solving complex problems, physical modelling and evaluation, require more attention when teaching physics at the appropriate school or university. The development of values can be made more explicit and conscious in physics lessons, when physics teachers and teachers are trained in strategies for the development of values.

In conclusion, the concept of "knowledge in motion" in combination with theories in the workplace can offer a useful conceptual union for studying the nature of professional knowledge that students of technical specialities are taught after vocational training courses. This suggests that professional knowledge, rather than as a dichotomy, is perhaps more correctly viewed as distributed and networked. This has facilitated some of the ways in which teachers can, through continuous professional development activities, transmit it through networks and recording devices from class to class. These two conceptualisations begin to offer explanations of how professional training programmes based on codified and propositional knowledge cannot offer students a sufficiently complete learning experience. The research presented here requires further work to more fully determine the paths that teachers of vocational schools pave between classes and workplaces for their students. There is also a lot of work to be done on how to support teachers of vocational schools in implementing effective opportunities for continuous professional development and, indeed, in what contributes to effective continuous professional development.

A detailed analysis of the tests helped to identify biases, misconceptions and problems in the concept of the basic principles of physics and the work of this world. Some misconceptions were eliminated after the first semester and the course "Introduction to Physics". It is assumed that with the help of an interactive way of teaching physics, it would be possible to eliminate students' misconceptions, reduce the dropout rate of first-year students, and also increase the level of students' knowledge in introductory general physics courses, mainly in the field of mechanics. Further detailed analysis is necessary to more accurately identify misconceptions and tools to eliminate them.

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Conflict of Interest

None.

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Методика професійно-орієнтованого навчання фізики студентів технічних університетів

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Анотація

Актуальність. Вивчення технічної, і особливо фізичної, освіти на рівні середньої та вищої освіти в останні роки було зосереджено більше на вивченні концепцій або розумінні, ніж на розвитку навичок і цінностей. Найменше уваги приділялося розвитку цінностей. Викладання фізики на лекціях часто наголошує на поняттях та їхньому взаємозв'язку, тоді як лабораторні заняття також зосереджені на розвитку лабораторних навичок.

Мета. Мета дослідження - дослідити методику професійно-орієнтованого навчання фізики студентів технічних університетів.

Методологія. Систематичний огляд можна пояснити як дослідницький метод і процес для виявлення та критичного оцінювання відповідних досліджень, а також для збору та аналізу даних з цих досліджень. При популяризації фізики серед населення і заохоченні студентів до кар'єри фізика зазвичай акцент робиться на розвитку здатності розв'язувати фізичні задачі. В огляді цінності диплома з фізики випускники технічного університету наголошували на важливості навичок у своїй професії.

Результати. Передбачається, що за допомогою інтерактивного способу викладання фізики вдасться усунути хибні уявлення студентів, зменшити відсів першокурсників, а також підвищити рівень знань студентів у вступних курсах загальної фізики, переважно в галузі механіки.

Висновки. Концепція "знання в русі" в поєднанні з теоріями на робочому місці може запропонувати корисне концептуальне об'єднання для вивчення природи професійних знань, які викладаються студентам технічних спеціальностей після курсів професійно-технічної освіти. Це свідчить про те, що професійні знання, а не як дихотомію, можливо, правильніше розглядати як розподілені та мережеві.

Ключові слова: фізика, технічна освіта, методика навчання фізики, особливості технічної освіти, студенти технічних спеціальностей.