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The development of digital educational materials on tribology and their application in the formation of the professional competence of future physics teachers

Makpal Nurizinova[1*], Mazhyn Skakov[2], Ali Çoruh[3], Sherzod Ramankulov[4], Marat Nurizinov[5]

[1,2]*Sarsen Amanzholov East Kazakhstan University, Ust-Kamenogorsk, Kazakhstan.*
[3]*Sakarya University, Serdivan/Sakarya, Turkey.*
[4]*Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan.*
[5]*Modern Knowledge Schools, Manama, Bahrain.*

Corresponding author: Makpal Nurizinova (*Email: makpal.nurizinova@gmail.com*)

Abstract

Tribology, as a science that studies friction in mechanisms and their wear, occupies an important place in the combination of education, science and industry. Therefore, the training of future physics teachers in the field of tribology is one of the urgent issues. The purpose of this study is to increase the effectiveness of teaching in the field of tribology and to evaluate the effectiveness of digital education in forming the professional competencies of students in this field. This research also used the methods of modeling in a digital environment, software and constructive design along with the methods of theoretical analysis. In addition, a pedagogical experiment was conducted in which 86 students participated. The learning outcomes were assessed using questionnaires. As a result of the research, an elective course "Physical Foundations of Tribology" was developed and digital resources for the discipline are included in the educational program. The results showed that the students in these programs have a high level of professional creativity and a positive attitude towards creative educational activities. They are also sufficiently prepared to use digital learning materials for this course (M = 3.89). The educational and methodological test showed how well e-learning resources have been developed to help students master the discipline of tribology at a professional level. This is evidenced by the fact that about 75% of students demonstrated a high level of professional knowledge and abilities. The results of the study are recommended to be used at all stages of training future teachers.

Keywords: Digital resources, Future physics teacher, Tribology, Professional competence, STEM education.

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1. Introduction

The Republic of Kazakhstan is the first Central Asian member state of the Bologna process and a full participant in the European Higher Education Area. Kazakhstan's accession to the Bologna process made it possible to ensure the recognition of Kazakhstani educational programs and curricula, the academic mobility of students and teachers, the convertibility of domestic diplomas in the European region and the right of graduates to find employment in any country [1]. Currently, according to Industry 4.0 standards, employers believe that education is important [2]. The fourth industrial revolution requires that students have a penchant for innovation. Achievements in the field of science and technology in recent years require the constant development of the professional competencies of future physicists [3]. This is due to the fact that effective activities in industry are carried out by future physics teachers.

The concept of the most complicated phenomena occurring in research centers and installations, the modern technology used in their production and the explanation of the principles guiding their operation are all associated with presenting many challenges for students in both elementary and high educational institutions [4]. However, the methodology of teaching individual subjects using new STEM (Science, Technology, Engineering, Math) technologies in the process of training does not form a single system but remains at the level of individual proposals particularly for future physics teachers [5]. One of these areas is tribology. Tribology is a science that studies and describes contact interaction in the relative motion of highly deformable bodies. Tribology is one of the specific fields of physics [6]. It is widely used in the most important fields of human activity: electronics, information technology, mechanical engineering, energy, transport, biotechnology, medicine and the defense industry. The need for modern improvement of teaching methods in this industry follows from the above-mentioned features of the tribology industry. An increase in the number of qualified specialists in the field of tribology contributes to ensuring the economic stability of each country [7]. Consequently, one of the urgent issues is the teaching of disciplines that improve students' understanding of this field in secondary and higher education.

Tribology is distinguished by an in-depth study of molecular physics, solid-state physics, physics and physical chemistry of low-dimensional systems, colloidal and organic chemistry and methods of synthesis of polymaterials compared with traditional technical disciplines. The main stages of the development of tribology as well as the development of other sciences are associated with scientific discoveries and major inventions. Tribology is a truly international science. The theoretical foundations of tribology created by the works of scientists from various countries [8]. The works summarize the latest achievements in research related to various aspects of tribology over the past 2-3 years. Intensive work is underway in the field of surface engineering [9-11]. In technical universities, certain issues of tribology are studied. However, an analysis of the works devoted to this problem allows us to conclude that there are no such educational materials for pedagogical universities that train future physics teachers. At the same time, the study of the physical foundations of tribology at universities meets the principle of professional training and can significantly affect students' knowledge of the methodological foundations of modern science.

The integration of students' level of knowledge and the ability to participate in discussions based on limited or incomplete education taking into account the initial learning outcomes both at the program level and at the academic level is the basis of general professional competence. Professional competence is a complex, multilevel and dynamic process taking place at the stage of formation. Professionalism is an essential attribute of the personally and professionally significant qualities of an expert who has the necessary knowledge and skills to ensure his preparation for effective and appropriate actions. In today's rapidly changing world, the opportunity to develop professional competencies is becoming a necessity. Competence is considered in the research works of many foreign and domestic scientists including the competence of a future specialist [12-14]. We form professional competence through the physical foundations of tribology, i.e., electronic textbooks on a special discipline included in the cycle of specialized disciplines. Electronic learning materials are an educational resource that can be displayed in the form of written materials, pictures, simulations, quizzes and interactive multimedia tools [15, 16]. E-learning materials have an impact on improving students' ICT (Information and communication technology) skills [17] learning independence, increasing interest in learning [18] and are also effective STEM education tools [19, 20].

At the same time, future physics teachers should have the skills of fast and multifaceted processing, storage, presentation and interpretation of information, its application in the educational process and scientific activities using digital means. The use of digital educational resources in teaching activities will increase the level of formation and development of professional competencies among students as well as the effectiveness of training qualified specialists. Currently, digital educational resources have been developed and are used in almost all technical universities in the training process. Thus, Engel, et al. [21] introduced a modern, conceptual and visual introduction to physical chemistry. The authors emphasize the relevance of physical chemistry today and illustrate its relevance to the world around us using modern applications drawn from biology, environmental science and materials science. It includes an electronic textbook as well as a detailed explanation of circuit theory and analysis [22]. It helps students continuously broaden their knowledge by presenting the essential ideas in an organised manner. Step-by-step analysis methods provide a solid foundation for developing problem-solving skills. More than 1,200 tasks and almost 200 examples introduce a realistic engineering experience that will develop the ideas of a practicing engineer. However, the analysis of literary sources shows that the physical foundations of tribology lack the digital educational programs that are necessary in the process of training future physics teachers. This research makes it possible to improve knowledge in the field of tribology in preparation for future specialists in physics. In addition, the significance of the research is characterized by the introduction of new disciplines into the educational process, the development of new digital educational resources within the discipline and thereby the development of professional competencies in the field of tribology.

The following scientific and methodological issues will be resolved during this research:

- What are the features of the development of the professional competencies of future physicists in the field of tribology?
- What should be the content of training in the field of tribology?
- What is the place of digital educational resources in the development of professional competencies?
- What are the principles of the development and teaching of disciplines in the field of tribology?

The purpose of this work is to develop digital educational materials for the course of physical fundamentals of tribology and their use in higher education in the process of forming the professional competencies of future physics teachers.

2. Literature Review

2.1. The Physical Foundations of Tribology

In recent years, the role and importance of the field of tribology in science and technology have increased significantly. That is why research activity on the most important aspects of the latest discoveries in the field of tribology has developed.

The section on general tribology is a special science of physics that studies interrelated interactions in the relative motion of deformable bodies describing friction in interaction. Students in the "pedagogical physics" programme need to study the "physical foundations of tribology". The "Physical Foundations of Tribology" present some topics of molecular physics, fundamental laws of mechanics, processes of thermodynamics, laws of electrodynamics and the main scientific discoveries of metallophysics and materials science. Therefore, when preparing future physics teachers under the requirements of the time, it is important to provide detailed information about the mechanisms of formation and destruction of surface layers during friction, i.e. about the physical foundations of tribology. The stages of development in the field of tribology will be associated with the development of other sciences. It is also known that the field of tribology is associated with scientific discoveries in general physics and major inventions. Thus, it can be seen that the field of tribology is indeed an international science and the theoretical foundations of tribology have found their place in the works of many of its scientists in recent years.

Bhushan [7] gives the reader a clear understanding of tribology which is necessary for engineers involved in the design and reliability of machine parts and systems. In this edition, the author has included updated information on friction, wear and lubrication as well as completely redesigned material including the latest advances in tribology at the nano and micro levels as well as a revised introduction to nanotechnology.

In the textbook, Chichinadze, et al. [23] Fundamentals of Tribology for Technical Universities, the most dangerous and harmful types of wear (abrasive, adhesive, and hydrogen) which lead to negative technical and economic consequences, are considered. The theoretical and practical sections in the textbook are presented interrelatedly in such a way that modern concepts of the theory of external friction, wear and lubrication are most efficiently and effectively used in engineering practice in the development, manufacture, testing and operation of friction units of various machines and mechanisms.

Reviews of recent years written in the field of tribology have tried to present the results obtained during his research in this field and his prospects. According to Meng, et al. [24], about 1,000 peer-reviewed articles were selected from 3,450 articles published in 2020-2021 and considered representative achievements in the field of tribological research worldwide. The review examines the development of lubrication technologies, wear and surface development, bio tribology, high-temperature tribology and exceptional tribology describing a demonstration of the achievements of the latest fundamental and applied research in the field of tribology.

According to Rosenkranz, et al. [25], the search for intelligence is investigated with an emphasis on machine learning techniques and the incorporation of new knowledge into the tribological community to predict essential tribological parameters such as training ratios and mass media content. The work of our domestic scientists in the country can also be noted.

Nurizinova, et al. [26] and Skakov and Nurizinova [27] proposed to develop a methodology for preparing future physics teachers and students to master tribology. In addition, the necessity of the above proposal and the technological importance of tribology in industry are emphasized and proven. Various methods of scientific research were used, including analysis, synthesis and comparison of visual research results with well-known achievements to develop students' views on tribology. An elective course in tribology has been introduced into the program for physics students. Experiments related to the elective course were conducted.

2.2. Professional Competence of Future Physics Teachers

Physics as a discipline requires constant research work. The research work serves as a starting point for performing logical and mathematical operations in physics and as an observer of the connection between theory and practice. The development of fundamental research in the field of physics, the achievement of new results and the formation of creative innovations require that future specialists have professional competence, namely research competence. Many scientists have devoted their work to professional competence.

Antera [28] examines and discusses various interpretations of the professional competence of vocational education.

Tkachenko and Kulyk [29] present both traditional and innovative approaches to understand the goals, essence, content and expedient organization of laboratory classes based on the methodology of teaching physics. The article emphasizes the importance of combining modern technologies with educational experiments for the development of professional skills.

The methodological features and content of laboratory work for graduate students aimed at the formation of competencies in conditions close to practice are described.

Fomin and Petrushkina [30] and Yermekova, et al. [31] present brief results of an empirical study conducted among students of the Faculty of Physics and Mathematics aimed at determining the degree of professional competence formation. The conclusions contain a description of the level of professional competence of the future physics teacher. Thus, the professional competence of a future physics teacher is an integrated ability of the personality of a physics teacher.

2.3. Electronic Learning Materials

In our curriculum, we develop professional competencies using electronic textbooks developed in a special discipline. Electronic and digital educational resources are software and methodological complexes adapted to the independent solution of the problems of the educational process through the independent study of the theoretical and scientific content of knowledge on the materials necessary in education. They allow students to effectively implement a dynamic learning experience, providing knowledge of the subject in fragments of material or completely unlike traditional printed textbooks.

It is important to note that an electronic textbook is not just a digital version of a printed book where the content is simply copied in electronic format or processed with hyperlinks. Boldyreva and Burdinsky [32] and Suryani, et al. [33] investigated the impact of digital educational resources on students' social skills in research in the field of pedagogy. The results of these studies show that the effectiveness of digital learning resources in developing students' social skills has been proven compared to traditional printed textbooks.

The conclusions of Alfiras and Bojiah [34] assessing the degree of effectiveness of electronic and digital educational resources show that students support both formats have a higher propensity to use electronic and digital resources. In addition, it can be seen from the above studies that students' desire for electronic and digital resources depends on the content of the discipline, the complexity and the ease of knowledge.

Nevertheless, the literature review highlights the lack of digital and electronic resources aimed at teaching the basic concepts and fundamental knowledge of tribology which are crucial for the training of future physics teachers.

3. Materials and Methods

3.1. Research Design

This study consisted of the following three stages:

1. Determining the degree of readiness of physics teachers to study in a new innovative format: When determining the degree of readiness of future physics teachers in the field of tribology to study in a new innovative format, we used the Google Forms service to conduct surveys and evaluate the results. The survey was conducted on the psychometric Likert scale.

The content of the survey consisted of 15 simple statements in which respondents were asked to rate their readiness on a five-point Likert scale: I absolutely disagree, I disagree, neutral, I agree and I completely agree (see Figure 1). As a result, we were convinced of the extent to which students are ready to use innovative format materials in the educational process.

2. Development and implementation of electronic textbooks in the educational process: "Physical Foundations of Tribology" "electronic methodological guide for performing laboratory work on the physical fundamentals of tribology", "electronic methodological guidelines for practical classes in the discipline", "Physical Foundations of Tribology" for the elective course "Physical Foundations of Tribology".

When developing electronic textbooks for use in the course of mastering the elective course "Physical Foundations of Tribology", an analysis of educational goals and a long-term plan of a standard curriculum in this discipline was carried out; a review of foreign experience was conducted, an analysis of the collected material was carried out and effective pedagogical technologies and teaching tools were consistently selected during laboratory work with great attention to the specifics of the content disciplines.

Explanatory videos are provided for use in laboratory work as well as control and self-tests (see Figure 3) based on methodological guidelines for the organization of training in the course program.

3. Teaching of the elective course "Physical Foundations of Tribology" ' with the help of developed electronic manuals and checking their effectiveness with the help of experimental studies. This course will be included in the university's curriculum in 2020 and experimental work on electronic textbooks has begun since 2021. The effectiveness of mastering the theoretical material was evaluated according to the developed criteria after which students begin to perform laboratory work, according to digital educational material.

Laboratory work is performed in the form of a research project. A pedagogical experiment was conducted to determine the effectiveness of an electronic textbook on the physical foundations of tribology for the development of the professional competence of future physics teachers. The Statistics in Pedagogy application was used after an expert assessment of the respondents' professional competence levels to compare the distributions of students in the control and experimental groups.

Since the results were measured on an ordinal scale and the number of gradations was 4 (four levels), the sample size was quite large (n=50) and the program automatically performed calculations under the Pearson test (c2).

The final results were evaluated and the data obtained were processed.

3.2. Participants

In total, 86 students from 3 universities in Kazakhstan participated in the study: S. Amanzholov East Kazakhstan University, Khoja Ahmed Yasawi International Kazakh-Turkish University and South Kazakhstan Pedagogical University in 2022 and 2023, respectively.

Through the program of a parallel formative experiment, control (43 students) and experimental (43 students) groups were selected at universities. The expert assessment method was used to determine the levels (high, sufficient, medium and low) of students' competence.

3.3. Instruments

The means to achieve the goal of our research work are: accessible educational programs of universities, students of this educational program, teachers, a textbook for effective teaching of the elective course "Physical Foundations of Tribology" and textbooks.

4. Results and Discussion

86 students from 3 universities in Kazakhstan participated in the 2021 survey to determine their preparedness (see Table 1).

Table 1.
Survey participants.

University name	Educational program	Degree	Number of students
S. Amanzholov East Kazakhstan University	Physics, 6B01502	Bachelor's program	24
International Kazakh-Turkish University named after Khoja Ahmed Yasawi	Physics, 6B01503	Bachelor's program	35
South Kazakhstan State Pedagogical University	Physics, 6B01503	Bachelor's program	27
Total: 86			

We conducted a survey and assessed the findings using Google Forms. The psychometric Likert scale was used by Mumu, et al. [35].

The poll consisted of straightforward statements on a five-point Likert scale for respondents to rank their level of preparedness: Strongly disagree (1), disagree (2), agree (4), agree (5) and absolutely agree (see Figure 1) [36].

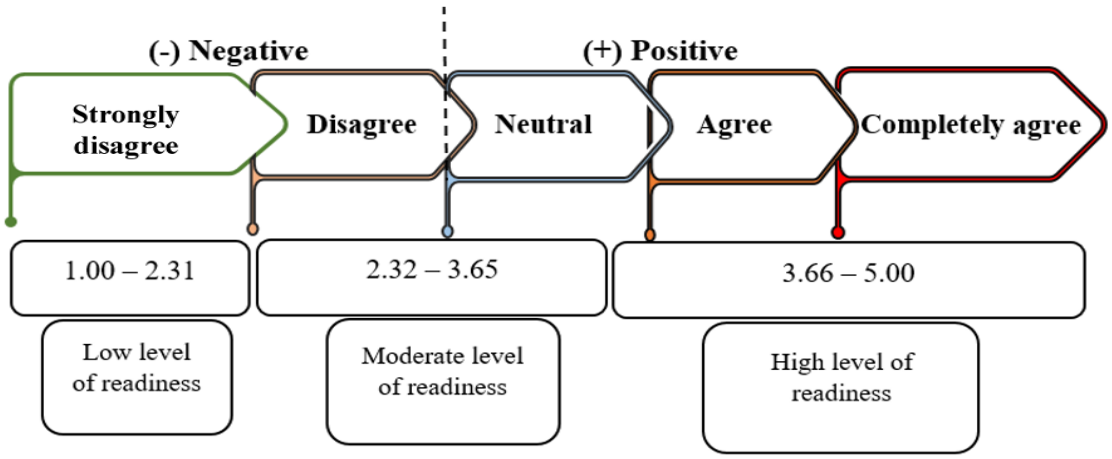


Figure 1.
Gradation of consent and the criterion of preparedness.

The participants were informed of the study's purpose and objectives and provided signed consent to take part in the educational trial prior to the survey.

The study's findings show how prepared physics educators are to learn in novel and cutting-edge formats. This is significant because it will help with the process of creating digital transformation policies for specific curricula within the context of future physics educators' thorough professional development. The sample's focus on a single career path is related to the need for a comprehensive analysis of students' creative preparation because these students have comparable needs with respect to the organization of the educational process and share the same competency requirements for employment as future teachers. Thus, students from three universities that shared comparable organizational and resource capacities and conditions together with one educational profile, «Physics» were chosen to carry out a pedagogical experiment. The average degree of students' preparedness needed to be determined because the innovative preparation of the students was evaluated within the confines of a single educational path [36]. The findings of a survey given to students to ascertain their degree of preparedness to enhance their digital literacy in the subject of tribology are displayed in Table 2.

Table 2.
The findings of a student poll about their willingness to advance their digital literacy in tribology.

No.	Statement	Mean score (M)	Level
1	I am attempting to provide novel findings in the field of tribology while performing fundamental studies in this field.	3.99	High
2	I am always looking for new ways to improve my knowledge in accordance with the new content of education in order to increase my professional competence.	4.24	High
3	I think it's beneficial to remain updated with tribology-related world events when working on a research paper.	4.19	High
4	I believe that the study of the field of tribology is positively influenced by the use of innovative technological tools.	3.87	High
5	I can use innovative approaches and new ideas in the fields of science and technology in the process of mastering the physical foundations of tribology.	3.97	High
6	I believe that perfect mastery of the tools of new technologies and their effective use contribute to improving the quality of research results.	4.02	High
7	I like to participate as a member of the research group in working with the latest innovative installations in the field of tribology.	3.35	Moderate
8	I am committed to the rapid adoption of new innovative developments in the field of tribology and their further development.	4.07	High
9	I have well-developed skills in observing the ethics of scientific research and adequate communication and cooperation in the digital environment.	3.95	High
10	I can effectively work in an online library and other digital educational resources that meet modern world standards.	3.97	High
11	I can effectively use asynchronous digital tools in scientific research and educational processes in the field of tribology.	3.88	High
12	I follow the safety rules in the digital environment which are related to research and the educational process.	4.12	High
13	I can save printed learning materials by effectively using digital education and digital research tools.	3.60	Moderate
14	My aim is to improve my scientific creativity, mobility and critical thinking skills through the use of digital research and educational resources.	3.48	Moderate
15	Using digital resources in digital education and research allows me to perfectly build my own learning and research trajectory.	4.26	High

According to Table 1 on tribology, the assessment results for students' readiness to increase their digital literacy indicate that students' average score was high (M = 3.96). They were reasonably prepared to use the digital educational resources for the course “Physical Foundations of Tribology”. The following are the main electronic Internet-based educational tools that are currently available [37] interactive environments (interactive applications, physical multimedia models of phenomena and processes), virtual physical laboratories (the system contains course demonstrations, explanations and simulation models of laboratory work which allows you to anticipate the results and mathematically verify their reliability), multimedia electronic textbooks, reference books and encyclopedias, educational databases and knowledge control tools (a system of tests and tasks).

We developed digital teaching resources such as an electronic textbook and a series of lab exercises covering the theoretical underpinnings of tribology to carry out the objectives given to this endeavor.

The development of an electronic textbook involves considering various requirements concerning the content, educational information organization, interface design, electronic textbook design, and theoretical frameworks for information perception laws and focusing the attention of students when learning new knowledge.

Thus, the electronic textbook on the physical foundations of tribology uses the content and structure developed in accordance with the logic of the educational process.

There is currently a wide range of software with which you can create electronic textbooks: iSpring Suite, CourseLab, TurboSite and several others. The TurboSite program is a small program for creating a free website and an electronic textbook. The effectiveness of this program lies in the fact that every teacher can create a website and electronic textbooks for himself easily and quickly.

The algorithm for creating an electronic teaching aid for performing three laboratory works on the “Physical Foundations of Tribology” using the TurboSite program is shown in Figure 2.

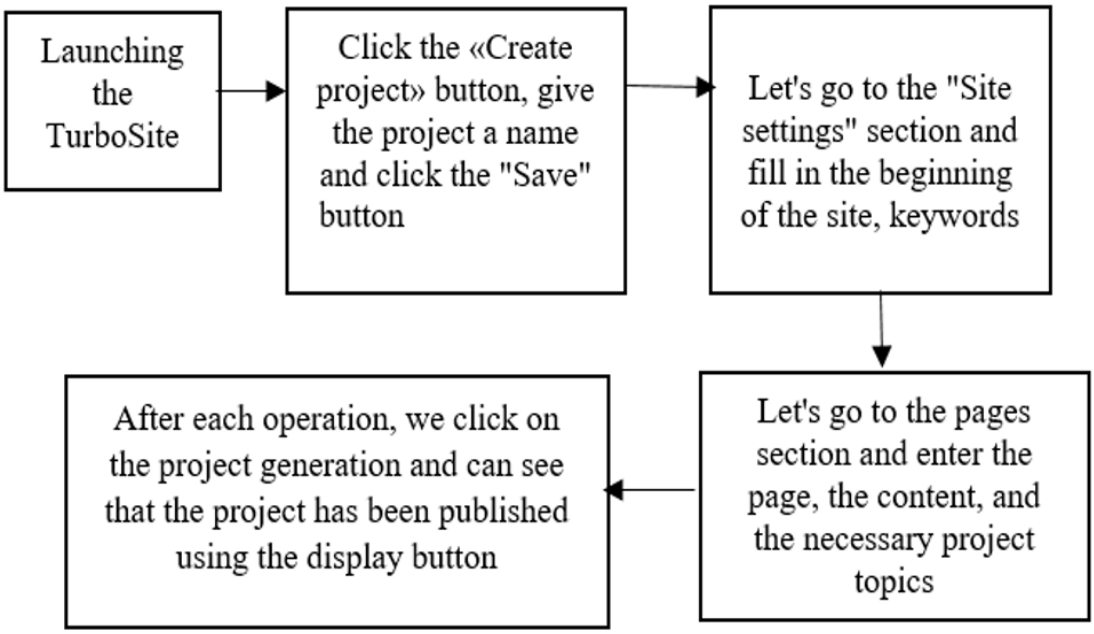


Figure 2.
The algorithm of operation using the TurboSite program.

By clicking on the create a project button, we create our own electronic textbook and start working. In addition, you can select standard templates for an electronic textbook here. The project we have created will be called guidelines for performing laboratory work on the physical foundations of tribology (in Kz). We find the “public_html” link and click, then click the “index” link and exit the interface by clicking on this button (see Figure 3, 4).

Figure 3.
The interface of the electronic teaching aid (in KZ).

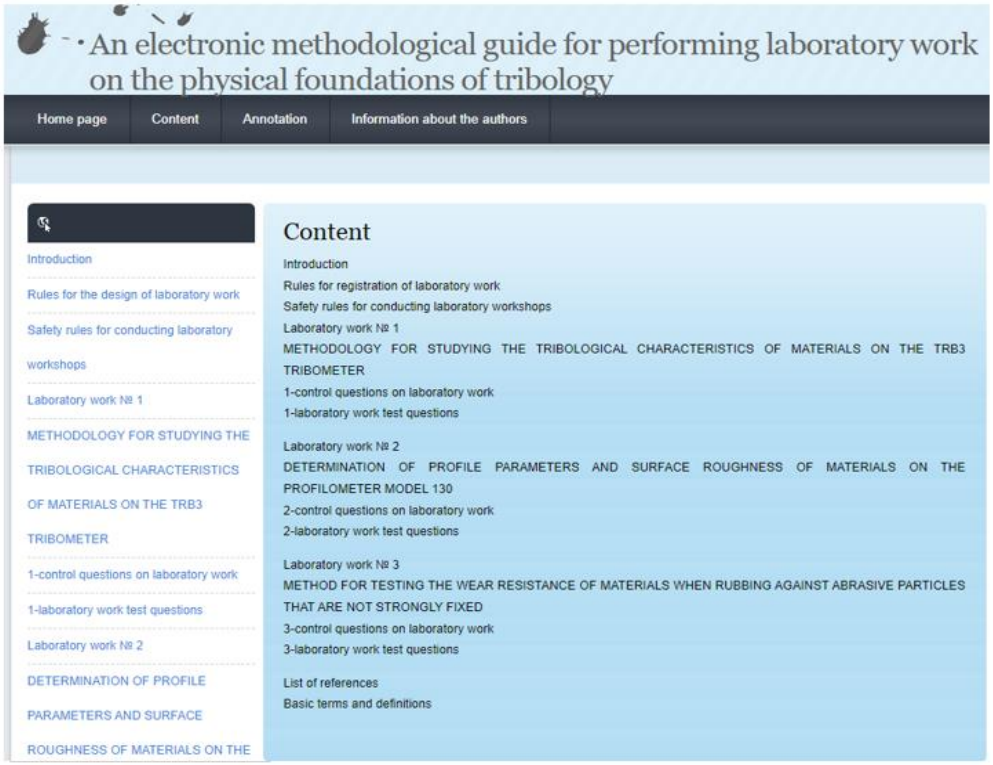


Figure 4.
The content of this electronic training manual (in KZ).

The content of this electronic training manual includes the following information: Content; basics terms and definitions, introduction, rules for the design of laboratory work, safety rules for conducting laboratory workshops, No. 1-laboratory work, 1-control questions on laboratory work, 1-laboratory work test, No. 2-laboratory work, 2-control questions on laboratory work, 2 laboratory work test, No. 3-laboratory work, 3-control questions on laboratory work, 3-laboratory work test, used literature and video on laboratory work (see Figure 4). It can be seen that this electronic teaching aid has a navigation panel on which all sections of the textbook are displayed. For example, we can access the content and methodology of the laboratory work on topic No. 2, determination of profile parameters and surface roughness of materials on the profilometer model 130 by clicking on «№2 laboratory work. The goal of the work is to acquire knowledge about surface roughness parameters and develop the ability to use the profilometer model 130 to calculate the roughness parameter Ra. Required tools and supplies: Surface roughness is measured using samples using a profilometer model 130. Theoretical information on the surface roughness of a machine part and its characteristics is given. It also provides information about devices for measuring roughness such as a profilometer (see Figure 5).

Figure 5.
Model 130 profilometer.

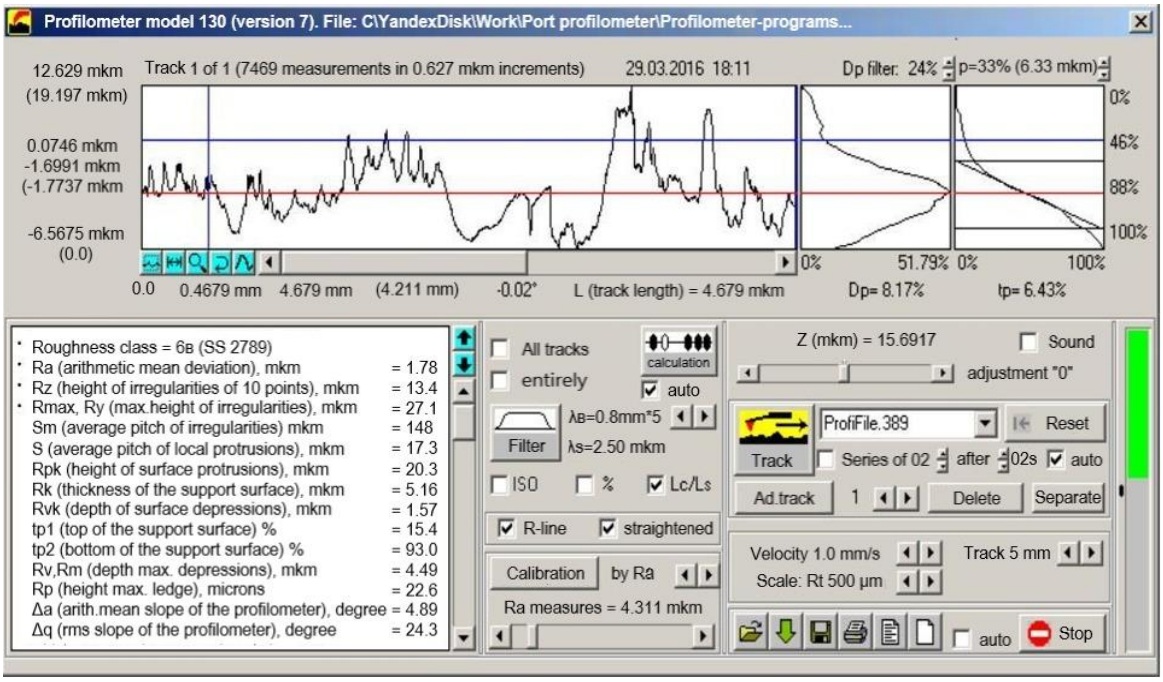


Figure 6.
Model 130 profilometer control window.

The contact profilometer, model 130 with a degree of accuracy 1 (2) as per GOST 19300-86 is intended to measure the parameters of profile and roughness in compliance with the midline system (state standard 25142-82) and the ranges of values specified by state standard 2789-73. The action of the profilometer is based on the principle of feeling the irregularities of the measured surface with an inductive sensor probe (a diamond needle) during tracing (moving the sensor along the measured surface at a constant speed) converting the movement of the probe into an analogue digital signal with further digital signal processing (see Figure 6). The block diagram of the procedure for performing work on the profilometer model 130 is shown in Figures 7 and 8.

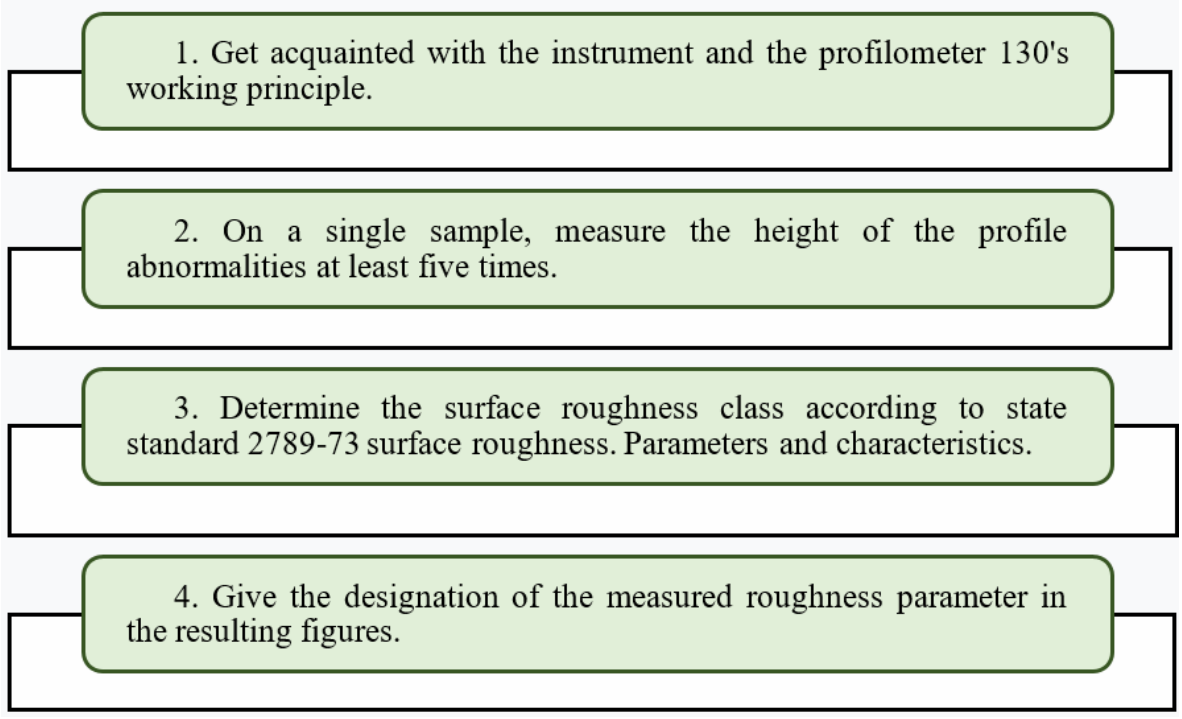


Figure 7.
The assignment for carrying out laboratory work.

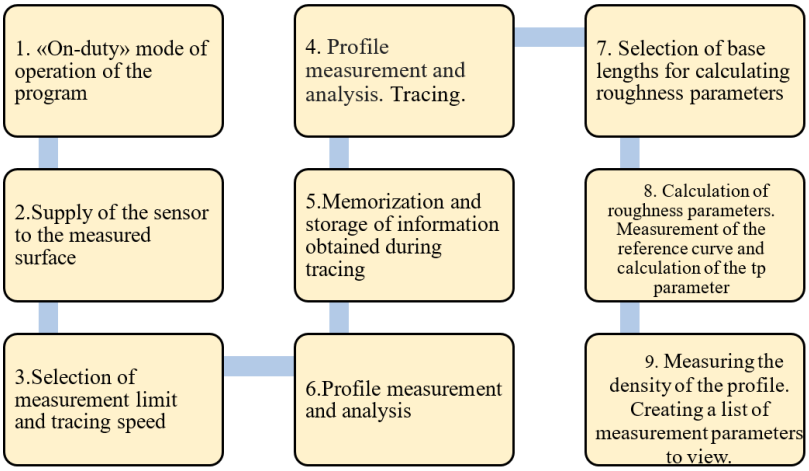
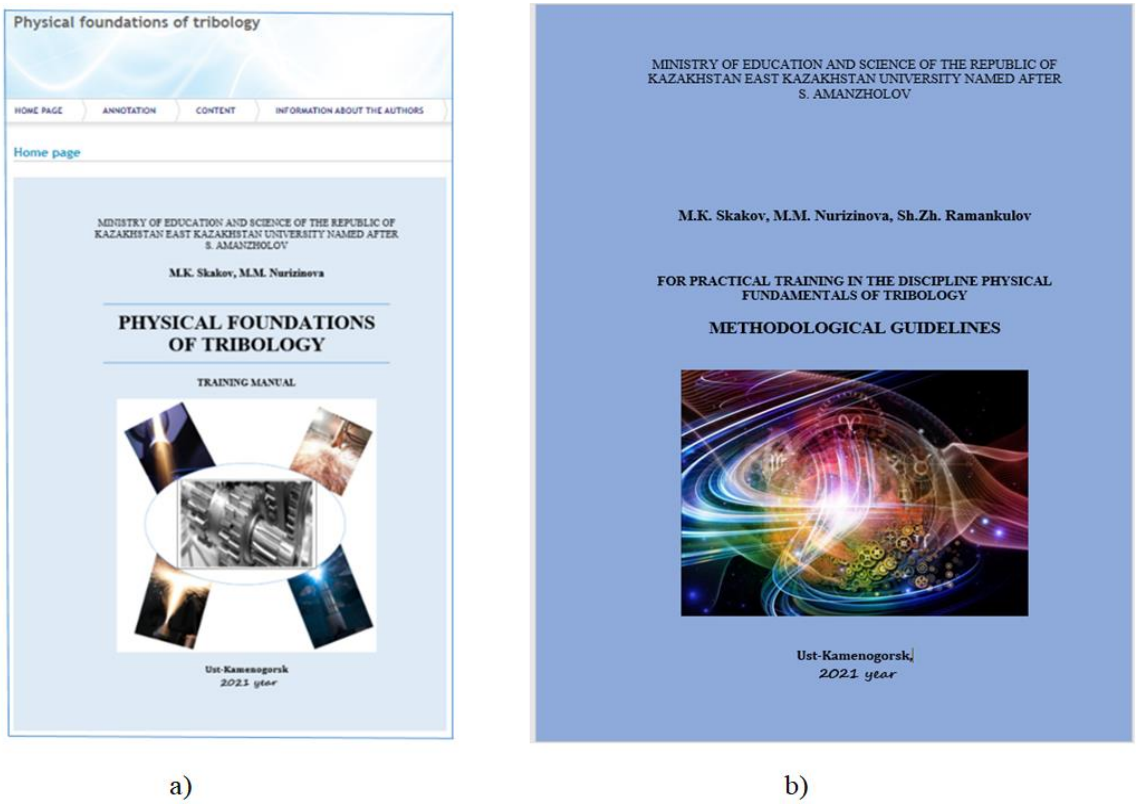


Figure 8.
The procedure for performing work on the profilometer model 130.

The navigation bar contains a video block. By clicking on the video on the laboratory work button, we go to the video clips of the activities of the scientific staff of the scientific research center Surface Engineering and Tribology of the Amanzholov East Kazakhstan University:

1. https://www.youtube.com/watch?v=s2hdwX16qhs (Kenesbekov A.B. Tribometer.Getting to know the TRB3) (3rd generation tribometer device).
2. https://www.youtube.com/watch?v=IZVEBXLESWA (Magazov N. Introduction to the device «Tribometer TRB3» for tribological research).
3. https://www.youtube.com/watch?v=sz_MCSdbNOQ (Baizhan D.R. Introduction to the Profilometer 130 device for determining the surface roughness of a material).
4. https://www.youtube.com/watch?v=l2U6Cx_69wI (Magazov N.M. Introduction to the device for measuring microhardness «Metolab 5021»).
5. https://www.youtube.com/watch?v=Q5Qa1PpPmGs&t=46s (A research project based on Amanzholov University.).

Electronic textbooks have been developed in a similar way, Physical Fundamentals of Tribology (focused on studying the basic knowledge of tribology (see Figures 9a and 10a). Electronic methodological guidelines for practical classes on the subject Foundations of Tribology (aimed at performing practical classes on knowledge in the field of tribology) (see Figure 9b and 10b).



a) b)

Figure 9.
Interfaces of electronic manuals (a, b).

a) b)

Figure 10.
Accordingly, their certificates of entry into the state list of rights to objects protected by copyright of the Ministry of Justice of the Republic of Kazakhstan (a, b).

Each student must study theoretical material (lectures, diagrams, instructions and memos), perform practical work on the topic (get a positive assessment), take a test with theoretical questions and small practical tasks (get a positive assessment for this course using a developed electronic textbook on physical foundations and tribology) and start performing laboratory work. Digitization of the educational material and its division into topics allowed students to have more convenient and flexible access to the material as well as use various interactive elements to facilitate the learning process such as case studies, project methods, problem situations, learning through play, group and pair work and the game method. Lectures play a significant role in the instructional process in higher education institutions. The student must receive information not in the Gotov form but in the process of search and creative adaptation. The focus of the form aimed at solving this problem is to expand the possibilities of case technologies in higher education. A sample of the educational case on the topic of materials for the tribological systems is shown in Table 3.

Table 3.
Educational case on the topic materials of tribological systems.

Stages of the educational case	Actions following the educational case
Research on the topic	Case study: Materials of tribological systems (Physical foundations of tribology).
Task	Create a collection of tasks on the topic of materials for tribological systems.
Description	Clarification of indicators under the set of tasks on the topic of materials for tribological systems.
Task	Your task is to create a collection of tasks on the topic of materials for tribological systems.
Position and role	You are a well-known author of tribology manuals.
Lecture hall	Your customer is a publishing house.
Problem	The publishing house asked us to create a section of the problem book corresponding to the topic materials of tribological systems but with new subjects unfamiliar to students. The book is aimed at future physics teachers.
Creative product	You need to offer a task book for 2-3 book pages (In addition, you can write an introductory article to the collection).
Evaluation criteria	Commercial success requires that the tasks correspond to the topic and are diverse and interesting.

According to the digital textbook, the effectiveness of mastering the theoretical material was evaluated according to the developed criteria after which students began to perform laboratory work (see Figure 4). Laboratory work is performed in the form of a research project.

A pedagogical experiment was conducted to determine the effectiveness of an electronic textbook on the physical foundations of tribology for the development of the professional competence of future physics teachers. The pilot study involved 86 students from three universities in Kazakhstan in 2022 and 2023. Control (43 students) and experimental (43 students) groups were selected at universities in accordance with the program of a parallel formative experiment. The expert assessment method was used to determine the levels (high, sufficient, medium and low) of students' competence.

5. Conclusion

The results of an assessment of future physics teachers' preparedness for digital literacy in tribology (M = 3.89) are presented in this research. They have a high degree of creativity, a positive outlook on cutting-edge learning experiences and the necessary preparation to use digital learning resources for the Physical Foundations of Tribology course.

These findings served as the foundation for the creation of an electronic tribology educational resource that can be used in the classroom preparing the physics teachers of the future. The Electronic Methodological Guide for Performing Laboratory Work on the Physical Foundations of Tribology, Electronic Methodological Guidelines for Practical Classes and Physical Foundations of Tribology are among the electronic textbooks that have been developed and implemented into the educational process of the Physics educational programs.

The analysis of the results of a pedagogical experiment to evaluate the effectiveness of digital educational resources developed under the goals and objectives of a study focused on teaching the physical principles of tribology showed the presence of dynamics indicating a significant increase in the level of professional competence among students in the experimental groups. At the end of the pedagogical experimental training process, about 75% of the students in the experimental groups showed a high level of professional knowledge and abilities. Accordingly, about 60% of the students in the control groups showed a high level of knowledge in tribology.

The proportion of students in the experimental groups reflecting a high level of motivation to engage in tribological activities was 6.74% higher compared with the indicators of students in the control groups. In addition, in the experimental groups, the proportion of students with sufficient motivation was 8.26% higher than in the control group. Accordingly, the proportion of students with average motivation was 9.39% higher. Students with low motivation in the experimental group were 5.61% lower than the control group (see Figure 11).

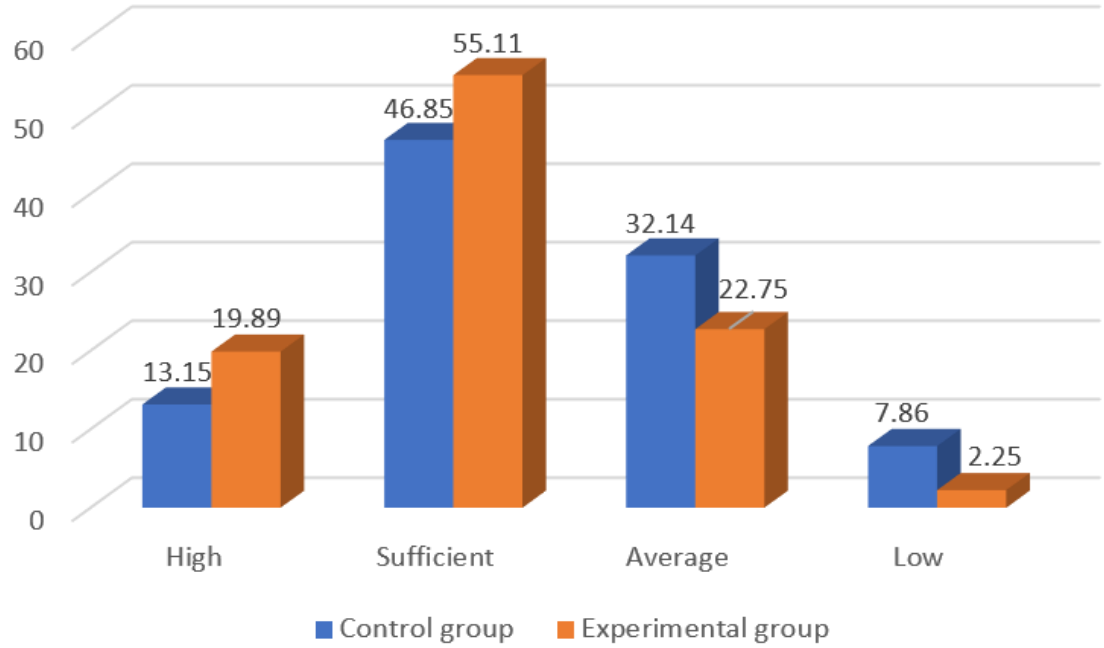


Figure 11.
The levels of professional competence of students in the control and experimental groups (in percentage).

In addition, it can be noted that the use of electronic and digital educational resources in the educational process has a positive impact on the thinking of students. These results provide new insights and recommendations for future research regarding the development of personal qualities and indicators of the professional competence of future physics teachers. The methodology "statistics in pedagogy" was applied to expert assessments of the levels of professional competence following the indicators of students in the control and experimental groups to demonstrate the truthfulness of the research results. The sample size was 50 (n = 50), the program automatically gave the results of calculations using the Pearson test (c2) taking into account the fact that the results of the pedagogical experiment were evaluated on a four-level ordinal scale. The results of statistical analysis on the obtained quantitative indicators confirmed the effectiveness of electronic and

digital resources (reliability level: 95%). This proves the positive impact of electronic and digital educational resources on the academic performance of future physics teachers, an indicator of professional competence. It confirms that the conclusions about the motivation of future physics teachers to study physical knowledge in the field of tribology are not accidental.

The pedagogical experiment also demonstrated the benefits of incorporating the tribology-specific electronic educational and methodological complexes that have been built into university curricula for future physics instructors. It is demonstrated that the student can independently use the created electronic resources to discover the answers to his inquiries without the assistance of a teacher or supervision.

In addition, it has

- The opportunity to use the necessary material many times at any convenient time.
- The ability to organize independent work.
- The ability to use multimedia tools to make the content more visual, understandable and entertaining.
- The opportunity to test your knowledge.

Thus, this paper shows the necessity and expediency of developing a digital educational method on tribology and its use in the process of training future physics teachers at a university to increase their level of professional competencies.

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