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To cite this article: I V Batsurovska *et al* 2024 *J. Phys.: Conf. Ser.* **2871** 012013

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Journal of Physics: Conference Series **2871** (2024) 012013 doi:10.1088/1742-6596/2871/1/012013

Online control of educational results of the unit "Electricity" in the conditions of blended learning

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Abstract. The article describes the technology of online control of educational results of the unit "Electricity" in the conditions of blended learning. It was determined that during the online stages of studying unit "Electricity", reverse communication is an urgent issue when receiving information in a distance format, and online control is designed to support the organization of a modern training session. Three topics have been singled out in the unit, in the context of which it is appropriate to develop control measures. Topic I "Electric Field in a Vacuum" focuses on the study of electric field strength, potential, the relationship between strength and potential, the electric dipole, and the circulation and flow of an electric field. Topic II "Electric Field in a Substance" involves the study of the electric field in dielectrics and conductors in an electric field. Topic III "Electric Current" includes general laws of electric current, electric circuit, current in a circuit with a capacitor, and current work and power. There are outlined the different types of tests: graphical, calculation, animated, audio that form the means of online control in the context of the outlined unit. The developed technology of online control of educational results of the unit "Electricity" provides for an organic combination of the presentation of educational materials with control measures. The research methodology involved the analysis and synthesis of scientific, pedagogical, methodological sources and empirical methods, as well as the analysis of the obtained results. Before the introduction of the developed technology and after the completion of the experimental work, a study was conducted, which included an analysis of the quality of knowledge when studying the specified topic. The obtained results before and after the experiment were tested using the Pearson statistical test χ^2.

1. Introduction

In connection with the pandemic [1] and the introduction of martial law in Ukraine [2], there is a need to modernize the education system. The practice of using blended or distance form of learning dominates [3,4]. Forms and methods of education are being improved, new technologies for learning and providing educational content are emerging [5,6]. In particular, during studying the unit "Electricity" in the context of studying of discipline "Physics", there is the need in assessment of its quality. This applies both to the assessment of the level of knowledge, skills and professional competences of students, and to the quality of the educational services provided to them in the context of electrical engineering education.


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Both the organization of the educational process and the quality control of education remain the subjects of numerous studies and discussions [7, 8]. During remote stages of electrical engineering education, reverse communication when receiving information in an online format becomes an actual issue. Also, it is necessary to be noted that any submission of information must be monitored for assimilation by the higher education applicants. The main requirement for control measures of the activities of higher education applicants is the professional focus of monitoring in the conditions of distance learning. In order to achieve the objectivity of control in the conditions of distance learning, the requirements of informativeness, validity and reliability of control, differentiation of verification should be followed.

The aspects of distance and blended learning are being investigated with by many scientists, in particular research on the impact of distance and online learning [9,10]. Researchers investigated distance learning quality assessment [11], there were considered perceptions of distance learning during the COVID-19 pandemic [12]. The scientists investigated the impact of video conferencing during emergency distance learning [13]. Also there were examined the technology and instructor dimensions and academic performance of distance students [14]. The evaluation of the distance learning combining webinars and virtual simulations [15, 16] and the problem of professional training of electrical engineers is widely studied in pedagogical theory [17].

Over recent years, theorization of energy democracy has brought additional nuance to practice-based imaginaries and associated definitions theory [18]. The authors note the need to study different aspects in the energy sector [19, 20], current issues of modern electricity generation [21], production of electricity from renewable sources [22]. The researchers take into account that the studying of the specialists in the field of electrical engineering is conducted on the basis of many years of experience in the construction and operation of electricity consumption systems, the experience of the world electricity industry, and the modern computer technologies [23]. The issues of control and monitoring during distance learning are devoted to works [24–26]. Labour market needs for engineers with enhanced knowledge in electrical engineering and renewable energy [27]. Innovation of engineering teaching methods based on multimedia assisted technology is covered in works of some authors [28]. The scientists in the studies focuses on applying knowledge engineering techniques in control engineering education [29]. The researchers analyze some aspects of quality control and efficiency of electronic educational and methodological complexes of educational disciplines usage in the educational process [30,31]. The investigation considers the problem of an interface for educational platform, which is fully effective for achieving the outcomes of educational activity [32]. There were investigated the learning tools of informational and educational environment [33], application of 3D models of electrical engineering in the performing laboratory work [34], but the technology of online control of educational results of the unit "Electricity" in the conditions of blended learning was not the specified subject of the study.

The aim of the article is to develop of technology of online control of educational results of the unit "Electricity" in the conditions of blended learning.

2. Methods

The research methodology involved the analysis and synthesis of scientific, pedagogical, methodological sources and empirical methods, as well as the analysis of the obtained results. Learners in the experimental group studied the topic with only one control measure, while in the experimental group a system of control measures was offered. The implementation of the technology of online control of educational results of the unit "Electricity" in the conditions of blended learning was provided by a system of tests of various types (graphical, calculation, audio, animated) and control work, which involved solving problems and presenting them in the online education system. The study of the unit "Electricity" in the conditions of blended learning involved the use of a quiz, complex tests and the final test. The study of the topic

"Electricity" was accompanied by an online course. Before the implementation of the developed technology and after the completion of the experimental work the study was conducted. It included an analysis of the quality of knowledge of studying the specified topic. The obtained results before and after the experiment were tested using the Pearson χ^2 statistical test [35].

3. The implementation of technology of online control of educational results of the unit "Electricity" in the conditions of blended learning

During the organization of the educational process, the tutor must take into account the purpose, content, means of pedagogical communication, his role and the role of students in the pedagogical system, functions, types and methods of control. Systematicity is associated with a variety of forms and methods of control.

Blended learning in this study will be understood as a flexible learning technology, which consists of a combination of classroom learning and tasks in the online environment. Auditory work is accompanied by control in the classroom, and non-auditory work is accompanied by online control with the help of learning tools, including test control, which includes various types of tests, modular and final estimation measures, which include the performance of problem tasks. Online control within the framework of extracurricular work of students may involve various types of tests, assignments and monitoring of learning activities in the online environment. There are outlined the following types of test questions that form the complex and final test according to the proposed technology: graphical, animated, audio and calculation. There are presented the examples of the different types of tests in the context of the unit "Electricity" (figure 1).

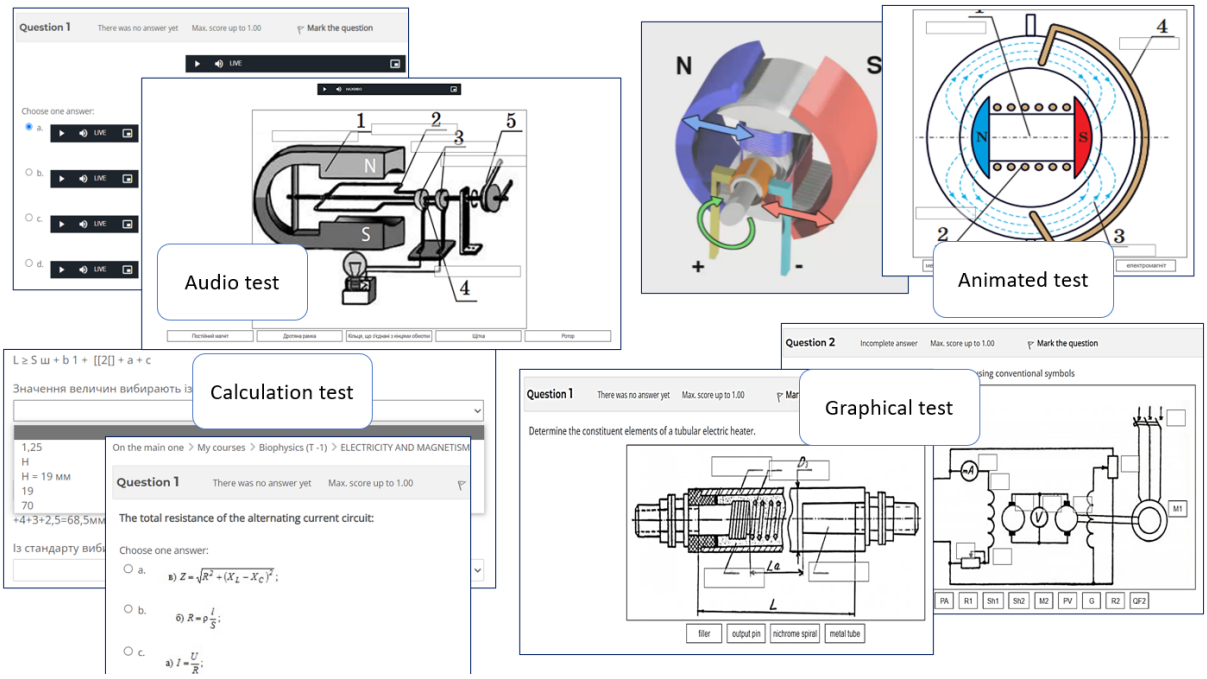

Figure 1. The examples of the different types of tests in the context of the unit "Electricity".

The calculation tests can vary in complexity and may cover different areas of science. The purpose of a calculation test is to measure a person's numerical reasoning skills, problem-solving abilities and mathematical fluency. The student must compute, then input the numerical response. With the use of the following type of tests, applicants of higher education can improve

their speedy calculation skills as well as their understanding of the theoretical, technical, and mathematical domains.

The audio test is a control measure that involves fixing the level of knowledge acquisition at a given interval of mastering educational content. The essence of the audio test is that the student has the opportunity to listen to an audio question and options for possible audio answers to this question. After listening, the student chooses the correct answer. Audio tests are relevant in the educational process due to the fact that modern students prefer audio files to text and even video files. Therefore, the development of this type of test tasks must necessarily be accompanied by modern audiovisual content. The use of this type of test tasks prevents mechanical selection of the answer, activates memory and the degree of assimilation of educational content. Therefore, in the context of online control, the use of audio tests is relevant.

The usage of a graphical test aims to develop professional competences through the training of visual perception and work with engineering drawings, diagrams, and other graphic objects in the conditions of blended learning. This type of test offers a chance to deepen awareness of certain processes and technical systems within the complex, serving as an addition to the theoretical study of teaching materials, practical applications, and laboratory work. Test that allows to drag a visual picture into a text field allows to analyse and distinguish between different types of educational content. A description of graphic items, procedures, intricate systems, and engineering machine components is provided for the work. Student should examine the suggested objects and graphic images, then put together the description and the matching graphic image. These tests can help with analytical skill development, memory training, and visual perception training. The goal of the graphical test is to help students develop their ability to perceive engineering items visually.

Based on a plane or spatial representation, graphical test allows users to move words to a graphic image. The visual tools have been carefully chosen, and they feature pertinent sections that could be explained in a classroom. Text explanations offer a way to bring up information about the aspects of the suggested visual image.

The logical visualisation of plane or spatial figures and the integration of their constituents are the main objectives of the graphical test for dragging images to images. It is possible to drag the elements to the appropriate area of the drawing with the task of studying the physical processes or complex components of the electrical equipment. Thus, without the need for specialised equipment, these type of tests allow for the development of practical skills as well as the training of visual memory and familiarisation with the practical aspects.

Based on GIF animation of physical processes, an animated test is presented. It is required to select one of the suggested images in order to restart the entire process. The processes of simulating the physical interaction of solids, the motion of particle, liquid, and gas systems, the simulation of dynamic motion, and the spatial animation of geometric forms may all be seen in animated simulators. Animated training simulators are a great tool for classrooms that lack certain necessary equipment. It makes it possible to carry out physical investigations that need specialised equipment and comprehend their working principles.

There are outlined the structural components of studying the unit “Electricity”. The unit consist of three topics: Electric Field in Vacuum, Electric Field in Substance and Electric Current (figure 2).

Topic I “Electric Field in a Vacuum” focuses on the study of electric field strength, potential, the connection between strength and potential, the electric dipole, and the circulation and flow of an electric field. Topic II “Electric Field in Substance” involves the study of the electric field in dielectrics and conductors in an electric field. Topic III “Electric Current” for study includes general laws of electric current, electric circuit, current in a circuit with a capacitor, and current work and power. The technology of online control of educational results of the unit “Electricity” is presented in figure 1.

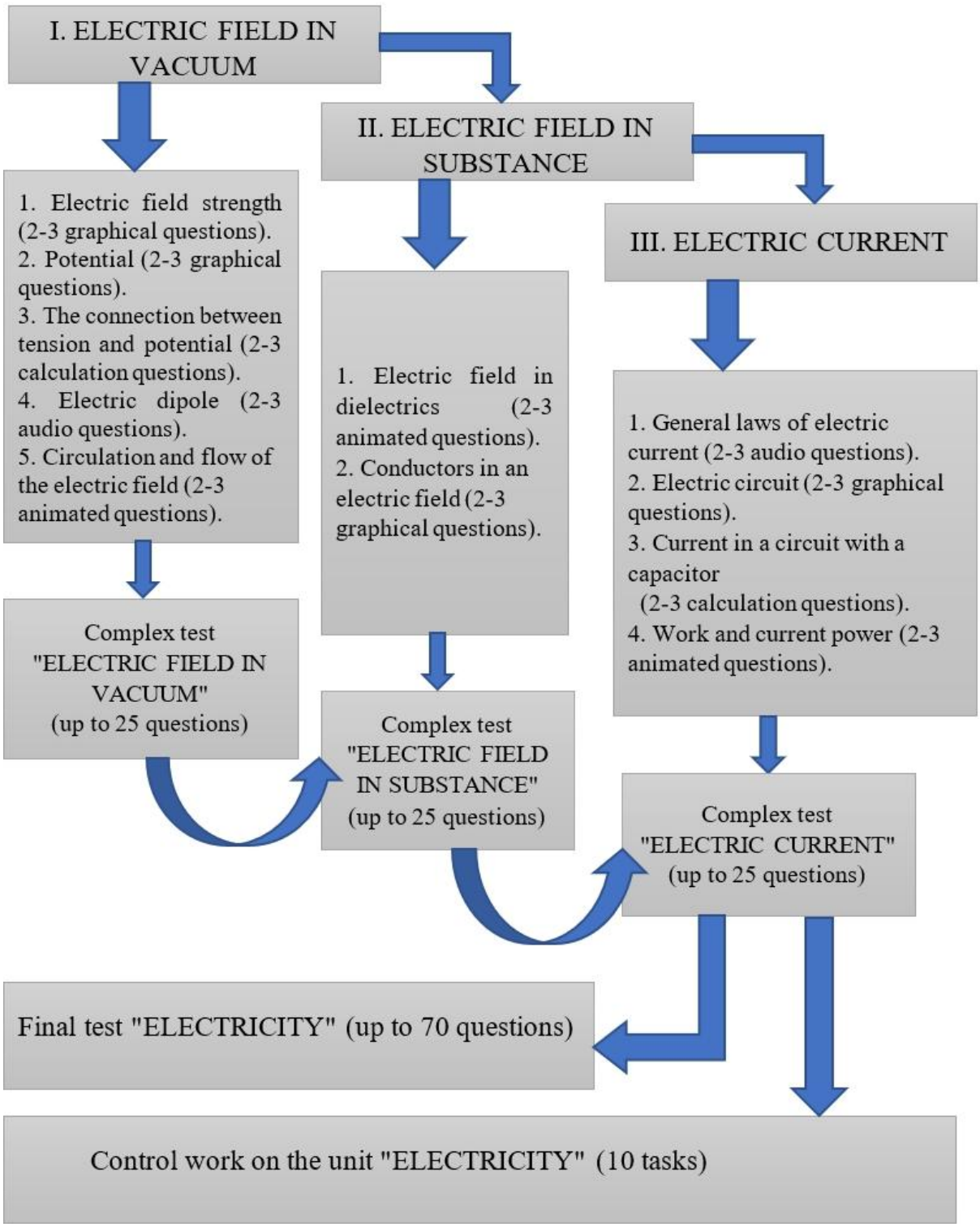

Figure 2. The technology of online control of educational results of the unit "Electricity" in the conditions of blended learning.

There are considered the technology of online control of educational results of the unit "Electricity" in the conditions of blended learning. The study of the topic I "Electric Field

in a Vacuum" involves five control quizzes. For choosing questions for a quiz, there is a need to avoid double interpretations of the answer. The answer to each quiz question should be very specific. It is necessary to select quiz questions of approximately the same difficulty level. It is advisable to offer no more than 2-3 quiz questions for each part of the topic (electric field intensity, potential, relationship between intensity and potential, electric dipole and circulation and flow of an electric field), which makes a total of 10-15 questions. The study of topics II "Electric Field in a Substance" and III "Electric Current" in the conditions of blended learning also involves quizzes. Accordingly, for the second topic, there is a need to make 4 to 6 questions for aspects such as the electric field in dielectrics and conductors in an electric field. For the third topic – 8-12 questions in the field of general laws of electric current, electric circuit, current in a circuit with a capacitor and work and power of current.

After each topic, higher education applicants are offered an complex test containing no more than 25 questions. In the context of making test, the requirements are the following: the clear language, short questions that not exceed half a minute, short and concise answer options.

Upon completion of all three topics, the higher education applicant must complete a final test on the unit "Electricity" in the conditions of blended learning and the control work that involves the solution of 10 problem tasks. A fully solved problem requires an abbreviated record, explanations, drawings (if necessary), derivation of the working formula, calculation and answer. Tasks are completed in writing and in the form of a photo report - a single pdf file - sent in the online course system.

The final test can contain different types of questions: multiple choice, matching, include practice questions, both text formulations and audio. The final test is offered for passing in the time allocated by the online education system, at the rate of 1.5 minutes per test task. If the test will contain 70 test tasks, then there is a need to outline such a test with a time of at least 90 minutes. The technology of online control of educational results of the unit "Electricity" in the conditions of blended learning involves an organic combination of presentation of educational material with control measures.

4. Results

In the conducted pedagogical experiment, the effectiveness of the technology of online control of educational results on the topic "Electricity" in the conditions of mixed learning was investigated. The experiment included 431 participants, divided into control group – 215 students and experimental group – 216 students. The study covered three different thematic blocks: "Electric field in vacuum", "Electric field in substance" and "Electric current", which included the study of various aspects of electricity. Each of the topics was complemented by a system of control measures, which covered the use of various types of tests and control works, allowing to assess the mastery of the material by students. The purpose of the experiment was to develop and implement technology that allows to effectively organize the educational process, providing high-quality online monitoring of learning results. An important aspect of the experiment was the provision of feedback in the conditions of distance learning, as well as the assessment of the quality of students' knowledge before and after the implementation of the developed technology. The results were analyzed using the Pearson statistical test, which made it possible to evaluate the effectiveness of the proposed system. It is important to note that during the analysis of the results, not only the impact of the proposed technology was taken into account, but also the methods used in the learning process. Such an approach to the research made it possible to comprehensively evaluate the effectiveness of blended learning, including the organization of the educational process, the use of various forms and methods of control, as well as the role of the tutor and students in the pedagogical system.

There are presented the results of the experimental work in the form of a table. Thus, the levels of studying the unit "Electricity" during online learning in the control (CG) and

Table 1. Levels of studying the unit "Electricity" during blended learning in the control and experimental groups at the beginning of the experiment.

Level	EG,%	EG, n_i	CG, %	CG, n_{i1}	$(n_1 - n_{i1})^2$	$(n_1 - n_{i1})^2/n_{i1}$
A	1.85	4	2.33	5	1	0.20
B	7.41	16	8.37	18	4	0.22
C	17.59	38	13.95	30	64	2.13
D	21.30	46	22.33	48	4	0.08
E	25.46	55	26.05	56	1	0.02
FX	26.39	57	26.98	58	1	0.02
Total	100	216	100	215		2.67

Table 2. Levels of studying the unit "Electricity" during blended learning in the control and experimental groups at the end of the experiment.

Level	EG,%	EG, n_i	CG, %	CG, n_{i1}	$(n_1 - n_{i1})^2$	$(n_1 - n_{i1})^2/n_{i1}$
A	11.11	24	5.12	11	169	15.36
B	19.91	43	14.88	32	121	3.78
C	25.00	54	22.33	48	36	0.75
D	24.54	53	22.33	48	25	0.52
E	14.35	31	21.40	46	225	4.89
FX	5.09	11	13.95	30	361	12.03
Total	100	216	100	215		37.34

experimental (EG) groups at the beginning and at the end of the experiment are presented in tables 1, 2.

At the beginning of the experiment, the empirical value of Pearson's χ^2 is 2.67.

At the end of the experiment in the control and experimental groups the empirical value of Pearson's χ^2 is 37.34. It is defined the degree of freedom ν =5 ($\nu = k - 1, k = 6$). It is defined a critical value for the degree of freedom $\chi^2 crit$ (11.070; 15.086) for levels of statistical significance $\rho \leq 0.05$ and $\rho \leq 0.01$.

Thus, the obtained empirical value of Pearson's χ^2 before the experiment is less than the critical value. That is, $\chi^2_{emp} \leq \chi^2_{crit}$, which means belonging to the zone of insignificance. The levels of studying the unit "Electricity" during online learning in the control and experimental groups at the beginning of the experiment do not have significant differences.

The obtained empirical value of Pearson's χ^2 at the end of the experiment is less than the critical value. That is, $\chi^2_{emp} \geq \chi^2_{crit}$, which means belonging to the zone of significance. The levels of studying the unit "Electricity" during online learning in the control and experimental groups at the end of the experiment have significant differences.

It is obvious that the author's technology of online control of educational results of the unit "Electricity" in the conditions of blended learning is effective. The result of the implementation of the technology is the mastery of the components of the outlined unit, and the acquisition of high-quality knowledge and skills in electricity.

5. Discussion

Blended learning offers flexibility in terms of time and place of learning, allowing students to access materials and assessments at their own pace and convenience. In subjects like Physics, where hands-on experimentation may be combined with theoretical learning [36], online assessments provide flexibility for students to demonstrate their understanding of electricity concepts at their own pace and convenience [37]. They can access assessment materials and resources anytime, anywhere, which is particularly beneficial in blended learning environments where students may have varying schedules and learning preferences.

Blended learning allows for the integration of diverse assessment methods, including both traditional assessments such as exams and quizzes, as well as innovative online assessments such as interactive simulations, virtual labs and multimedia presentations. This variety ensures that students' understanding of electricity is assessed comprehensively, catering to different learning styles and preferences [38].

This timely feedback is crucial for promoting self-regulated learning and facilitating students' progress towards mastery of the subject. It enables students to identify areas of weakness and seek additional support or resources as needed, fostering a more dynamic and personalized learning experience [39]. Online assessments can provide immediate feedback to students, enabling them to identify areas of strength and weakness in their understanding of electricity. Educational platforms generate valuable data on students' performance, which can be analysed to gain insights into their learning patterns, misconceptions, and areas needing further reinforcement.

Authors and researchers advocate for the use of data analytics tools to inform instructional decisions and personalize learning experiences in the unit of electricity [40,41]. Online assessment platforms often generate detailed analytics and data on student performance, which can inform instructional decisions and interventions. Educators can use this data to identify trends, assess the effectiveness of instructional strategies, and tailor their teaching approaches to better meet the needs of individual students or groups.

Blended learning facilitates the seamless integration of formative assessment (ongoing assessments used to monitor students' progress) and summative assessment (final assessments used to evaluate students' overall achievement) [42]. By continuously assessing students' understanding of electricity throughout the unit, educators can identify learning gaps early on and provide targeted interventions to support student learning [43]. The challenge of online assessment is maintaining academic integrity and preventing cheating. Educators must implement strategies such as proctoring tools, randomized question banks, and plagiarism detection software to uphold academic standards and ensure the integrity of assessment results. Learning environments lend themselves well to the development of critical thinking and problem-solving skills in the context of electricity. Through interactive online activities, collaborative projects, and real-world applications, students are encouraged to apply their knowledge to solve practical problems related to electrical concepts.

Blended learning promotes accessibility and inclusivity by accommodating diverse learners, including those with disabilities or learning differences. Online resources can be designed to be accessible to all students, ensuring equitable access to educational materials and assessments in the unit of electricity [44]. It allows for differentiation and personalized support for diverse learners, including those with special educational needs or English language learners [45]. Educators can provide additional or alternative assessment options to ensure all students have equitable opportunities to demonstrate their understanding of electricity concepts. Blended learning environments offer opportunities for authentic assessment tasks that reflect real-world applications of electricity concepts. For example, students could collaborate on designing and troubleshooting electrical circuits using virtual simulation tools or working on practical projects that integrate theoretical knowledge with hands-on skills [46].

6. Conclusion

Blended learning, which combines traditional face-to-face instruction with online learning components, offers unique opportunities for assessing educational results in the context of studying Physics. Online control of educational results in this context can be highly effective if implemented thoughtfully.

Online control of educational results in the unit "Electricity" within a blended learning context offers numerous benefits, including flexibility, accessibility, diverse assessment formats, real-time feedback, data-driven insights, authentic assessment opportunities, academic integrity safeguards, support for diverse learners, and increased engagement and motivation. However, it's essential for educators to thoughtfully design and implement online assessments to maximize their effectiveness and ensure they align with the learning objectives and needs of students.

The study confirmed the effectiveness of the proposed technology of online control of educational results in the context of blended learning. The implementation of the proposed technology contributed to the improvement of the quality of students' knowledge and skills on the unit "Electricity". The technology made it possible to effectively organize the educational process, combining the presentation of educational material with control measures. The systematic use of various forms of testing and control works contributed to deep learning of the material. The use of innovative methods of online control, including graphic, audio, animation and calculation tasks, ensured high interaction and involvement of students in the educational process, and also contributed to the development of professional competencies. Analysis of the results of the experiment using the Pearson statistical test showed a statistically significant increase in the level of educational results in the experimental group compared to the control group, which confirms the effectiveness of the developed technology.

Prospects for further research are the development of competency-based types of control for the topic "Magnetism" in online courses, which will allow expanding the use of online control technology in other areas of physical and engineering education.

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