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THE EFFECTS OF BLENDED LEARNING APPROACH ON STUDENT MOTIVATION FOR LEARNING PHYSICS

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Abstract. *The topic of Direct current is one of the areas where the physics students' lack of deep understanding was identified. The aim of the research was to examine the effect of the blended learning approach on students' motivation for learning physics. The sample included 128 upper-secondary school students from Novi Sad (Serbia) with an average age of 16. Of these, 64 students made up the experimental group and 64 students made up the control group. In the control group, the students did not actively participate in simulated experiments, and in the experimental group learning was realized through the application of the blended learning approach (BLA), since the students had an active role in conducting simulations themselves. The obtained results showed that BLA contributes to the overall motivation for learning physics, as well as self-efficacy and physics learning value. Also, an increase in motivation was observed in two dimensions of motivation among female students in the experimental group. The implementation of BLA caused a significant increase in the motivation of students with lower achievement. Therefore, the main recommendation, based on the obtained research results, would be for teachers to apply BLA to a greater extent because it contributes to student motivation.*

Keywords: *blended learning approach, experimental research, physics education, student motivation*

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Introduction

Contemporary research tends to include as many factors as possible (cognitive and non-cognitive) to better explain student performance, so different approaches to teaching have been developed in recent decades. Some of these approaches are based on the application of new technologies. One of the examples of the application of new technologies in teaching and learning is the blended learning approach (BLA). BLA is a combination of home and classroom activities (Gamage et al., 2022; Wei et al., 2022). This approach encourages students to take more responsibility for their learning and provides them with more challenges in the learning process. In order to achieve satisfactory learning outcomes, students should determine their needs and preferences, set learning goals, choose effective learning strategies, use available learning resources, manage time, etc. (Sabah, 2020).

Research has shown that most students consider physics an interesting but difficult subject, with a heavy workload and rapid progress through the curriculum (Angell et al., 2004). The explanation of this student perception is that physics deals with the study of complex processes that require the application of different types of representations, such as formulas, mathematical calculations, graphic representations, and requires conceptual understanding at an abstract level. The existing teaching practice has often been criticized (Osborne & Collins, 2001) indicating that students perceive teaching methods as boring and uninteresting, and that the teaching content of science subjects is too repetitive with too little challenge.

Teachers play a very important role in raising students' interest in physics and related subjects. Changing their practices is the key to changes in student performance (Saleh, 2014). Positive changes in teaching practice are reflected in the structuring of curricula to be based on active learning and the greatest possible application of theoretical knowledge in practical teaching activities (Koludrović & Ercegovac, 2015). The application of BLA has proven to be particularly useful in classes with 30 or more students because it allows

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each student to actively participate in the teaching process (Dorocki et al., 2022). Also, BLA proved to be useful when studying extensive material because part of the material can be processed through online activities, which allows the time allocated for schoolwork to be completed with additional clarifications and active discussion.

Experimental tests of theoretical laws, which are most often carried out in laboratories, are especially characteristic of physics. The laboratory work itself has a significant impact on students' understanding of the material (Radulović et al., 2016). However, students often have difficulties in performing the experiment, and pay more attention to assembling the necessary apparatus (e.g., electrical circuit) than to the measured results (Ajredini et al., 2014). Using BLA, students can perform online measurements, process the obtained results, and watch the prepared recordings in order to better prepare for the next lesson. Prepared in this way, the students can assemble the necessary equipment much more easily and can focus more on the discussion of the obtained results. Also, through better preparation for class, students feel more confident in their own knowledge and skills. On the other hand, the teacher has more time to provide additional support to students who need it. According to Rice et al. (2013, according to Wei et al., 2022), students who feel more supported by teachers also feel more competent and are more active in class, which is especially characteristic of mathematics and natural sciences. It is the feeling of security in one's own knowledge and the support of the teacher that are directly correlated with motivation (Wei et al., 2022). The feeling of self-efficacy is connected with setting goals, choosing activities, invested effort and expected outcomes (Bandura, 2001), that is, with student motivation.

Besides self-confidence, motivation also plays an important role in learning. There are several different approaches to explaining the concept of motivation (Eccles & Wigfield, 2002; Ryan & Deci, 2000). One of the dominant approaches finds its theoretical foundation in the reasons and goals that drive an activity, distinguishing between intrinsic and extrinsic motivations that derive from Self-determination theory (Ryan & Deci, 2000). Intrinsic motivation results from activities in which an individual engages due to his own pleasure, interest, and desire for development (Ryan & Deci, 2000). The results showed that intrinsic motivation is associated with higher student performance (Skinner et al., 2017; Taylor et al., 2014). On the other hand, extrinsically motivated students engage in activities because of the consequences that follow (Ryan & Deci, 2000), which creates a desire to initiate and persist in a behavior (Reeve, 2010).

In this research, specific motivation is regarded as the motivation of students to acquire content in a certain school subject (Brophy, 1987, according to Vizek-Vidović et al., 2003; Zubac et al., 2021), that is, in physics classes. Motivation for learning natural sciences, according to Tuan et al. (2005) includes: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation.

Motivation is an area that has attracted the attention of researchers for decades, primarily because of the crucial importance of motivation for learning and academic achievement. However, research on motivation in the context of physics as a subject is limited, especially if the effect of BLA on student motivation is observed. One of the earlier studies was aimed at determining the motivation and barriers during the implementation of BLA using the Moodle platform (Sabah, 2020). It is clear that more research is needed to investigate the relationships between various motivational factors, the application of BLA and student performance, especially in the field of science.

Poor achievement in science in the standardized international testing raises a great concern in many countries. OECD has suggested that all countries can reduce their share of low-performing students by changing the teaching approach, by fostering expectations of high academic achievement for all students, and by creating supportive learning environments (OECD, 2016). With that in mind, it is important to analyze the effects of the applied learning approach to the students of different academic achievement, since the lack of understanding the material and the lack of learning skills might be the cause of the lack of motivation to learn physics. Raising the motivation to learn in low-achieving students is the goal of physics teachers and can lead to the better quality of the overall knowledge.

Another point of interest is the difference in gender participation in science. It has been discussed in numerous studies (Sagala et al., 2019; Taasoobshirazi & Carr, 2008; Young et al., 2011), and the greatest gender inequality is observed in physics (Ivie & Stove, 2000, according to Taasoobshirazi & Carr, 2008). Males have been found to have higher achievement on physics knowledge tests during both primary and secondary school (NAEP 2005), as well as higher self-efficacy and higher aspiration for physics-related careers (Young et al., 2011). To reduce inequalities in gender participation in physics, factors that affect girls' motivation to learn physics and make career in this field should also be analyzed.

The focus of this research was on the provision of relevant facts and a more complete understanding of the effects of BLA on learning abstract topics in physics. Thus, the aim was to examine the effects of blended learning approach to the motivation of students to learn physics, and the research question was: How does application of BLA motivate students of different gender and different achievements to learn physics?

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Research Methodology

General Background

This study examined the effects of blended learning approach and students' motivation to learn physics. The research was conducted in physics classes where direct current is studied in the second grade of upper-secondary school. In order to examine students' motivation towards learning physics, quasi-experimental design was conducted using a control and an experimental group of students. In the experimental group, BLA was applied, while in the control group, the teaching of the same material took place in the classic way, using the frontal method. After the teaching was conducted in different ways, the motivation for learning physics was examined in both groups. They were also tested with a knowledge test in physics with the aim of determining mastery of the material.

For this research, the topic of Direct Current was chosen because it was found that there was a lack of deep understanding of these concepts among students (Stocklmayer, 2010). Also, the chosen topic abounds with abstract and complex concepts. Although students have already encountered the concepts of electrons and electric current, these concepts remain unclear to them during later levels of education, as shown in the work of Şahin and Yağbasan (2012). It is precisely the vagueness and complexity of the concept that can cause a decrease in student motivation to study the topic. Rapid changes in the development of technology and its implementation in learning are not always accompanied by detailed examinations of their effects on student performance.

Research Design

The research used a pedagogical quasi-experiment with parallel groups, experimental (E) and control (C). Groups were constructed from already existing classes. The schools where the pedagogical experiment was conducted were chosen so that the conditions in which the students work are completely identical in terms of classroom equipment. The pedagogical experiment lasted six weeks (three classes per week) and was organized in May 2018. It included the following topics:

1. Source of electric current and electromotive force. The current intensity and current density.
2. Ohm's law for a conductor. Electric resistance of a conductor, types of connection of resistors.
3. Joule-Lenz law. Ohm's law for a simple electrical circuit. Kirchoffs laws.
4. Electrical conductivity of metals. Ohm's law and Joule's law on the base of classical electronic theory of metal conductivity. Contact potential. Thermoelectric effect.
5. Electric current in liquids. Ohm's law and conductance of electrolytes. Faradey's law of electrolysis.
6. Thermionic emission. Cathode ray tube.
7. Electric current in gases. Types of electric discharge in gases. Plasma.

Students of the C group were exposed to these topics during class time. The teacher applied monologue method in presenting the content and had a dominant role in the class. In order to explain the specific content (such as the electron flow through the conductor, or Ohm's law), the teacher demonstrated some PhEt simulations, and students observed them and listened to his explanations. The role of PhET simulations was to show more clearly the abstract concepts related to the topic. Since it was shown that PhET simulations had a pronounced impact on understanding of the physical concepts, the same simulations were also used in E group to eliminate their effects to the students' achievement and motivation.

The students of group E were exposed to the same teaching content using a flipped classroom as a blended learning approach. All the necessary teaching material was provided on the Moodle platform and included written lectures and the same PhET simulations the control group watched, so students did not need to visit other sites and make their own search. The goal of this experimental design was to exclude other distractors and to ensure that students focus only on the teaching material. As part of online activities, students were obliged to study the provided material and to use simulations to conduct measurements themselves with the aim to observe the visual representation of the studied phenomena and to understand how the change of variables affected the obtained results. The material was programmed, so after completing a topic, students had to pass a test to continue to the next section. The aim of this progression was to ensure a complete understanding of the teaching content. During class time, a discussion on the topic was organized and facilitated by the teacher, in which any ambiguities were explained, and conclusions were reached on the basis of students' observations and understanding.

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Sample

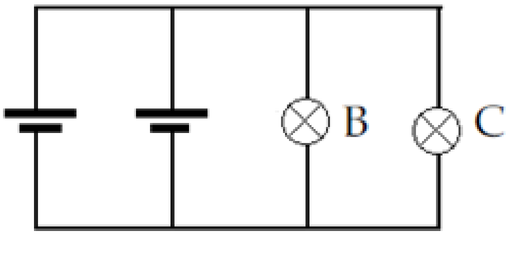
The research included students enrolled in second-grade classes of the natural sciences and mathematics educational profile from the two upper-secondary schools in Novi Sad, Serbia, with an average age of 16.27 (*SD* = 0.52). These were the classes taught by the same physics teacher. Two classes from one school were the control group (C), and two classes of the second school were the experimental group (E). There were 35-37 students per class, so the total number of students initially was 141. The students were informed that the research was anonymous and that their participation was voluntary, so that they could withdraw from the research at any time without consequences. After implementation of pedagogical experiment and exclusion of students who were missing from some classes or have incorrectly filled in the questionnaire, the total sample included 128 students – 64 students in the control group, and 64 students in the experimental group. There were 35 male students and 29 female students in the control group. Experimental group comprised 33 male students and 31 female students.

Instrument

A standardized SMTSL (Student's Motivation towards Science Learning) questionnaire, developed by Tuan et al. (2005) and translated into Serbian language by Olić et al. (2016), has been applied for initial and final measurement. The questionnaire consisted of 29 questions. Students expressed the level of agreement with the given statement on a 5-point Likert scale; where complete agreement was coded as 5, and complete disagreement as 1. According to the questionnaire, questions were divided into five subscales: self-efficacy, active learning strategies, physics learning value, performance goal and achievement goal. Standardized Cronbach's alpha in this study was .73; the Cronbach's alpha values for individual subscales were in the range .66–.85.

In order to determine the sensitivity of the applied teaching approach to students with different achievement levels, a knowledge test (Inventory of Basic Conceptions - DC Circuits-IBCDC) was used. The test was a translated version of the knowledge test created by Ibrahim Halloun (PhysPort, n.d.). The knowledge test comprised 29 items. Each correct answer was valued as one point. The obtained values of the discriminability index varied in the range of .159– .659, and the arithmetic mean for the knowledge test was .395. The difficulty index of the knowledge test was .36, which means that the tasks in the knowledge test were difficult for the students. The tasks that stood out as the most difficult were related to problem-based questions, e.g. *Is the electric field inside the light bulb fiber zero, or non-zero if the light bulb is the only consumer of a simple electric circuit? Is there a difference, and if so, what is the difference in light intensity between light bulb A, which is the only consumer connected to a simple circuit, and light bulb B, which is connected to a complex circuit* (shown in Figure 1)*?*

Figure 1
A Complex Circuit Related to the Problem Task



The items in the knowledge test were divided into three levels: basic, intermediate, and advanced. The basic level items (level 1) were the simplest type of tasks and tested factual knowledge of basic concepts related to electricity. Intermediate level items (level 2) required drawing certain conclusions based on given data and observing cause-and-effect relationships between physical quantities, while the items of the advanced level (level 3) contained a problem question that required setting up a hypothetical experiment and making assumptions about possible solutions.

In analysis of the achievement on the knowledge test, all students were divided into three categories: Level 1 students, who predominantly solved the problems from the basic level; Level 2 students, who solved the tasks

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from the basic and intermediate level, and Level 3 students, who managed to solve most tasks from all three levels of complexity (basic, intermediate and advanced).

Data Analysis

Since the values of skewness and kurtosis were outside the range -1 to +1 (Tabachnick & Fidell, 2007), non-parametric tests were used. The Mann-Whitney *U* was used to determine the difference between groups, while Wilcoxon rank test was applied to determine differences in student motivation for repeated measurements. In order to determine the contribution of interdependent predictors (applied learning approach and motivation) to students' achievement, a neural network modelling was applied as an alternative method of data analysis. All analyses were performed using SPSS 20.0 software.

Research Results

During the initial measurement, students of both groups showed the same motivation expressed by the median (Table 1). The difference in student motivation after the pedagogical experiment proved to be statistically significant.

Table 1
Differences in Students' Motivation to Learn Physics Before and After the Pedagogical Experiment

	Median for C group	Median for E group	Mann-Whitney *U*	*Z*	*r*
Motivation before pedagogical experiment	100.00	100.00	1936.00	-0.534	.05
Motivation after pedagogical experiment	99.50	102.00	1629.50	-1.996*	.18

Note. *$p < .05$

Among the students of the E group, there was an increase in the overall motivation for learning physics, while among the students of the C group a decrease in motivation was observed. Since motivation is a complex construct, it can be observed on five subscales. Table 2 shows the differences in motivation between control and experimental groups for different subscales after the pedagogical experiment.

Table 2
Differences in Students' Motivation to Learn Physics on Five Subscales of Motivation

	Self-efficacy	Active learning strategies	Physics learning value	Performance goal	Achievement goal
Median for C group	18.50	32.50	18.00	8.00	21.00
Median for E group	20.00	33.00	20.00	8.00	21.50
Mann-Whitney U	1598.00	2014.50	1439.00	1997.50	1899.00
Z	-2.159*	-0.160	-2.918**	-0.243	-0.718
r	.19	.01	.26	.02	.06

Note.*$p < .05$; **$p < .01$

The obtained results show that there are differences between the groups for the self-efficacy and physics learning value subscales. On the basis of Cohen criterium, the effect size on self-efficacy is small, and it is medium for the physics learning value subscale.

Differences in motivation between the initial and final measurements were tested using the Wilcoxon rank test (Table 3). The analysis showed that BLA contributed significantly to the application of active learning strategies and appreciation of the importance of physics as a science.

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Table 3
Differences Between Subscales of Motivation for Applied Teaching Approaches

Subscales	Control group Median				Experimental group Median			
	Pre	Post	Z	r	Pre	Post	Z	r
Self-efficacy	18.0	18.5	-1.15	.14	19.0	20.0	-1.85	.23
Active learning strategies	33.0	32.5	-0.53	.07	31.5	33.0	-2.39*	.30
Physics learning value	19.0	18.0	-1.17	.15	19.0	20.0	-2.83**	.35
Performance goal	8.0	8.0	-0.47	.06	8.0	8.0	-.13	.02
Achievement goal	21.0	21.0	-0.75	.09	21.0	21.5	-1.02	.13

Note.*$p < .05$; **$p < .01$

Since the selected subscales are (in)directly related to the internal motivation and interest in a deeper understanding of the teaching material, their effect on high achievement on the knowledge test was examined. A model of neural networks was used to determine this influence. In the applied neural network model, the overall percentage of correctly classified students in the training sample was 92.0%, while this percentage in the test sample was 92.5%. The AUROC (area under the ROC curve) assessed the accuracy of the model as good (.612). Table 4 shows the importance and the normalized importance of each predictor in the neural network in determining the achievement of the students. The obtained results indicate that both predictors influence the achievement of excellent results on the knowledge test.

Table 4
Importance and the Normalized Importance of Each Predictor of Students' Achievement

	Importance	Normalized importance (%)
Applied approaches	.380	61.4
Motivation	.620	100.00

The motivation to learn physics was measured in students of the three subgroups, in which they were placed according to the complexity of tasks they managed to solve in the knowledge test. (level 1 – basic complexity, level 2 – intermediate complexity, and level 3 – advanced complexity). In Table 5, the differences in motivation for learning physics between students with different levels of achievement is shown.

Table 5
Differences in Motivation for Learning Physics Between Students with Different Levels of Achievement

Level	Subscale	Self-efficacy	Active learning strategies	Physics learning value	Performance goal	Achievement goal
1	Pre	19.00	32.50	18.00	8.00	21.00
	Post	20.50	33.50	19.00	8.00	23.00
	Z	-1.71	-1.36	-2.10*	-2.18*	-0.08
2	Pre	18.50	31.50	19.00	8.00	21.00
	Post	19.00	32.00	19.00	8.00	21.00
	Z	-1.57	-1.62	-1.91*	-1.18	-1.30
3	Pre	16.00	31.50	18.50	7.00	20.50
	Post	17.00	34.00	20.00	7.00	21.50
	Z	-0.56	-1.48	-0.54	-0.36	-0.41

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The obtained results show that the differences in motivation are most significant among the students of the experimental group who are on basic level - able to solve only the simplest tasks and have only factual knowledge. Also, the difference was noticed for students on intermediate level on the physics learning value subscale. The differences in the motivation of the students on advanced level did not reach statistical significance on any of the investigated dimensions of motivation.

Although gender differences were not statistically significant in overall motivation, differences were observed in the self-efficacy subscale ($\chi^2 = 10.728$, $df = 3$, $p < .05$) and physics learning value subscale ($\chi^2 = 10.214$, $df = 3$, $p < .05$) where the values obtained on these two motivation subscales were higher for the girls in the E group.

Discussion

Considering the specificity of physics teaching, this research was conducted with the aim of examining the relation between BLA and student motivation for learning physics. The reason for choosing this direction of research was the observation that students perceive physics as an interesting but difficult and work-intensive subject (Angell et al., 2004) and the existence of various difficulties in understanding many concepts (Şahin & Yağbasan, 2012). On the other hand, numerous studies have shown that innovative teaching approaches contribute to increasing student performance (Lazarević et al., 2018; Maričić et al., 2020; Skinner et al., 2017; Taylor et al., 2014; Županec et al., 2022). Also, it was stated that visualization plays an important role as an effective tool in the teaching process (Dori et al., 2007; Vavra et al., 2011). Rastovac et al. (2021) found that students understood the teaching material more easily if it was presented to them through a visual approach and not just a textual one. However, research shows that not all visualizations are equally effective and suitable for every educational context (Vavra et al., 2011). For this research, the topic of Direct Current was chosen because the principles of direct current have been shown to create difficulties in learning for students of all ages (Stocklmayer, 2010).

The results obtained in this research have provided full answers to the postulated research question. Regarding the effect to the different approaches to the overall motivation of students to learn physics, it was shown that the application of visualization and new technologies in teaching do not necessarily lead to a significant increase in student motivation if there is no change in the role of students and teachers during the teaching process. The roles of students and teacher were different in experimental (E) and control (C) groups in this pedagogical experiment. Students of the C group had a passive role listening to the teacher and watching the demonstrations, while the teacher was active demonstrating simulations of the experiments. Students of the E group were active performing online measurements independently, while their teacher had the role of the facilitator. Changing the role of students from passive to active increased the overall motivation of the students of the E group for self-efficacy and physics learning value subscales. This is significant because self-efficacy is a belief in one's own abilities necessary for successful solving of tasks (Cheon & Reeve, 2015), and its increase, together with the realization of the importance of physics in everyday life, positively affects internal motivation. The result of increased intrinsic motivation is directly related to increased student achievement (Skinner et al., 2017; Taylor et al., 2014). Therefore, it can be expected that students focus more on the essential understanding of the material (Zubac et al., 2021) and tend to develop their own competencies that are in line with the subject (Senko et al., 2011).

Regarding the five subscales of motivation, it was shown that learning approach differently contributes to the increase of motivation in students at the different dimensions. It can be explained by looking at active learning strategies and motivation through the goal theory, which states that learning-oriented students show greater engagement in active learning strategies than achievement-oriented students (Vedder-Weiss & Fortus, 2012). Subscales that are directly or indirectly related to students' intrinsic motivation and genuine interest in the teaching content are recognized as important factors for learning and student performance (Hidi & Harackiewicz, 2000). So, by increasing intrinsic motivation, an increase in student performance can be expected, which was demonstrated by the neural network model. The obtained results indicate that both predictors influence the achievement of excellent results on the knowledge test.

Regarding the motivation of students with different levels of knowledge, research results also indicated a more significant contribution of the applied BLA in students with lower achievements. It was shown that perception of the importance of physics as a science of students who previously haven't performed well in physics classes can affect their motivation to learn. In addition, motivational orientation towards achievement stands out. This is a cause-and-effect relation: increasing the motivation to learn among those students causes a later increase in student achievement, which in turn causes a further increase in the motivation to learn. Students' perception of

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task importance is related to academic success because it affects students' effort and persistence (Eccles & Wigfield, 2002). When students are given tasks that they perceive as valuable and meaningful, they engage and exert more effort to achieve the goal (Pintrich & Schunk, 1996). Implementation of BLA showed a significant effect on students with lower performance, raising their awareness of the importance of physics in everyday life and making the teaching material more familiar to students by connecting it to the familiar everyday problems. The obtained data suggests that teachers should be more involved in the selection of activities that would indicate the practical importance of physics and its intrinsic value for the individual.

Regarding the effect of the respondent's gender on the overall motivation, the obtained results indicate that the statistical significance of the gender was not obtained, which is in line with other research (Saleh, 2014). The strength of BLA can be seen through differences in the motivation of female students. Using BLA, teaching material can be made more inclusive and adaptable to different groups. Such a positive result indicates the possibility of greater involvement and representation of women in physics. The problem of low representation of women in science, especially in physics, and low motivation for learning physics is a worldwide problem (Yeung et al., 2011), and the results of this research showed that the application of BLA contributes to certain subscales and female empowerment in terms of their own beliefs about the knowledge and skills they possess.

Finally, it is necessary to state the limitations of the research related to the need to include additional parameters to explain student motivation for learning physics, such as the educational status of parents and socio-economic aspects, and existence of some stereotypes. Also, future research should compare the results of BLA with other teaching approaches, especially those in which the active role of students is promoted. Within this research, it was shown that the application of visualization and new technologies in teaching does not necessarily lead to a significant increase in student motivation if there is no change in the role of students and teachers during the teaching process. Also, future research should look at differences in student motivation in other areas of physics. As a part of this research, the assumption was made that if the application of BLA has a contribution on student motivation when studying a complex and abstract topic such as Direct Current, that BLA would affect other topics that are clearer to students, such as Mechanics.

Conclusions and Implications

Due to the expansion of technologies and their increasing use in education without complete insight into their effects, the aim of this work was to examine the effects of blended learning approach to the motivation of students to learn physics. The research design used in this research was a pedagogical quasi-experiment with two groups, control and experimental. The research results showed that the application of BLA contributes to two dimensions of motivation - self-efficacy and physics learning value. The increase in self-efficacy and the understanding of the importance of physics in everyday life indicates an increase in internal motivation and a genuine interest in the teaching material and subject. Also, the results showed the strength of BLA to engage students with lower achievements, bringing the teaching content closer to them; as well as the greater motivation of girls, which could lead to their increased participation in physics classes.

Results of the research point out the significance of implementing BLA into teaching practice of physics teachers, because of its positive effect on student motivation. Also, awareness of the effects of BLA on motivation can help university teachers to provide adequate support for professional development and the development of beliefs of schoolteachers about learning and teaching physics. Obtained results are a recommendation to all universities that train future teachers to include the application of BLA in their practice, so that pre-service teachers can become better acquainted with this tool through their initial education. A well-prepared teacher more easily responds to the challenges of some new technical innovations that can be applied in practice. The importance of introducing innovations in higher education and better preparation of pre-service teachers for the teaching profession is gaining more and more importance; thus, the results of this research can indicate the way of applying BLA in the school practice of future teachers.

The limitations of the research are related to the need to include additional parameters to explain student motivation for learning physics, such as the educational status of parents and socio-economic aspects, examining the existence of some stereotypes. Future research should also compare the results of BLA with other teaching approaches, especially those in which the active role of students is realized. Additionally, the limitations of this research are related to the selection of the topic used for implementation of BLA. Only one topic – complex and abstract topic of direct current - was included in the research, so the obtained results cannot be generalized for the

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other physics disciplines. The future research could consider implementing BLA in other topics which are identified as difficult for the students, and also students of different ages could be included to obtain broader insight into the effect of BLA in teaching and learning physics.

Declaration of Interest

The authors declare no competing interest.

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