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THE EFFECTS OF CONSTRUCTIVIST PHYSICS LESSONS AND LABORATORIES ON STUDENTS' ACADEMIC SUCCESS

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Abstract: This study examines the impact of constructivist physics lessons and laboratory activities on middle and high school students' academic success. Utilizing the constructivist learning model, which emphasizes active student engagement, the research was conducted at Hyperion Theoretical High School in Chișinău, Moldova, involving 195 students across grades 6, 8, and 10. The study finds that integrating constructivist teaching methods — such as the 5E model, Flipped Classroom, and Early Physics Approach — positively influences students' academic performance at the middle and high school level. The results indicate a significant positive correlation between students' performance in laboratory work and their end-of-chapter evaluations. This highlights the importance of hands-on lab work in reinforcing learning and improving academic performance. The research reveals that, in middle school, girls perform better than boys in lab work and evaluations, but this difference diminishes in high school. The study suggests that constructivist lab work and assigned roles in group activities help reduce the gender gap in physics. The study indicates that physics is perceived as less masculine than traditionally thought, based on performance data and gender-related stereotypes. Despite some differences in performance, the overall constructivist environment in physics labs does not contribute to a negative experience based on gender.

Key words: constructivist physics lessons, school physics laboratories, academic success, summative evaluation, gender dynamics in physics learning.

1. Introduction

The pursuit of effective teaching and learning approaches in physics education has been a longstanding challenge for educators and researchers alike. One promising approach that has gained significant attention in recent years is the constructivist learning model, which emphasizes the active engagement of students in the learning process (Gil-Pérez et al. ,2002).

The Organization for Economic Cooperation and Development has recognized the potential of constructivist learning in science education and has highlighted the importance of understanding physics concepts through a process of active knowledge construction, where students are encouraged to communicate their ideas, explore their misconceptions, and build a comprehensive understanding of the subject matter (OECD, 2023).

The effects of applying constructivism in classroom are multiple and unequivocal. Thus, in terms of academic achievement for middle school students, constructivist teaching is more effective than traditional teaching, is not effective in terms of building students' physics identity, has some effect toward motivation and self-monitoring. Thus, a constructivist environment is preferred to a traditional classroom (Kim, 2005).

In order to fully participate in scientific practices and tackle real-life problems, individuals need more than just isolated knowledge or skills. They must develop a well-rounded scientific competence that enables them to understand phenomena and solve everyday issues while also preparing for future learning. Physics education should play a role in fostering this competence by focusing on fundamental concepts. Achieving this competence requires a continuous and cohesive educational effort over several years. Single lessons or standalone instructional units are inadequate; instead,

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instruction must be consistent with educational objectives across multiple lessons, units, and school years (Neumann & Nordine, 2022).

Constructivist methods improve students' cognitive learning activities and increase intrinsic motivation to learn physics (Beerenwinkel & von Arx, 2017). Also, implementation of constructivist-oriented teaching in daily classroom is difficult because we cannot permanently teach in a constructivist style. However, a constructivist approach based on mutual feedback and innovative didactic will always have a positive impact on learning (Karwasz & Wyborska, 2023). Thus, we can define at least three components of success in the physics lesson: a) constructivism as a basis for the student's cognitive effort (Calalb, 2023); b) the degree of student-teacher interaction or feedback (Hattie & Donoghue, 2016); c) innovative teaching (Margolis, 2020). Constructivism is also about communication – if students are more connected to each other and form coherent subgroups that communicate actively among themselves it could be a signature of active learning classes. Among the strategies that support this advanced level of communication, Peer Instruction, SCALE-UP and ISLE could be mentioned (Traxler et al., 2020). These research-based strategies increase the number of meaningful interactions between students in the classroom, with the greatest effect seen in strategies such as Modelling Instruction, SCALE-UP, and Context-Rich Problems (Commeford & Brewe, 2021).

Constructivist is inseparable from learning by doing, inquiry – based learning, reflexive learning or, in other words, from research-approach paradigm. For example, inquiry-based science education, in general, and the ISLE (Investigative Science Learning Environment) approach, in particular, are effective in helping students learn physics through hands-on activities while also fostering personal growth and empowerment (Brookes et al., 2020). Also, research approach paradigm combined with scaffolding and formative assessment and implemented during three academic years fosters students' scientific abilities to produce knowledge. In this way, the students' cognitive effort accompanied by the guidance from the teacher or scaffolding is the focal point in physics learning (Etkina et al., 2009). Scaffolding is a challenging strategy to implement because teachers find it hard to provide feedback that meets students' needs, especially when it involves probing the student's thinking process, particularly if it is non-scientific. (Dodlek et al., 2024). Ultimately this affects the quality of scaffolding.

Constructivism only makes sense in the lesson when students scientifically examine a real-life problem. Here we could provide the example of ISLE approach which has two major goals: a) students are engaged in practices that mirror real scientific research process; b) students' activities are focused on supporting their intellectual and emotional growth. To achieve these goals ISLE is based on three key elements: 1) learning process based on cognitive effort and learning tools which support inquiry; 2) multilateral assessment and community of learners; 3) mandatory time for presentations and discussions – in order to let students learn scientifically articulate their thoughts (Etkina et al., 2021).

As in this paper we will discuss the effects of constructivist lessons and laboratories on school students' academic success, we must emphasize that according to other research, lab conditions do not change significantly students' exam performance, but influence positively their attitude and experimentations skills (Smith et al., 2020). What is really important is the proper setting of objectives for each laboratory work and, depending on them, choose the appropriate strategy for organizing the work because different lab goals align with different types of pedagogy. For example, researchers distinguish two main types of labs: to reinforce concepts or to develop lab skills (Holmes & Lewandowski, 2020).

2. Methodology

2.1. Research objectives

The objectives of this research are structured on three main levels:

a) To analyze the impact of a combination of constructivist methods on students' academic success in studying physics in the sixth, eighth, and tenth grades.

b) To determine if there is a correlation between the marks obtained in laboratory work and those in summative assessments.

c) To highlight gender differences between boys and girls in studying physics and how these differences vary with age.

Thus, based on these three objectives, we formulate the research questions and hypotheses.

2. 2. Research hypotheses

H_1: In constructivist teaching, older students tend to perform better in physics compared to younger students.
H_2: There is a significant positive correlation between the marks obtained in the laboratory work and those obtained in the summative assessments in physics.
H_3: There are differences between the performance of boys and girls in studying physics.
H_4: Gender differences in studying physics vary with age from sixth to tenth grade.

2. 3. Participants

The research was conducted throughout the entire 2023-2024 academic year at Hyperion Theoretical High School, a public institution in Chișinău, Republic of Moldova. It should be noted that Hyperion is a neighborhood school located in the suburb of Durlești, near Chișinău. The study involved three 6th-grade classes (93 students aged 12: 50 girls and 43 boys), two 8th-grade classes (72 students aged 14: 41 girls and 31 boys), and one 10th-grade class (30 students aged 16: 21 girls and 9 boys). We used a random sample, with participants selected based on their enrollment in the respective grades, without applying any additional inclusion or exclusion criteria. The student population is predominantly from middle-income families, with a minority from lower-income households, making this sample representative of typical suburban schools in the region and offering insight into common educational settings in Chișinău. The same teacher taught all the classes involved in the study.

2. 4. Research Instuments

The results of the laboratory work conducted throughout the school year and the summative assessments administered at the end of each chapter were analyzed. According to the curriculum, in the 6th grade, four laboratory experiments and five summative assessments were completed within the 34 allocated hours. In the 8th grade, four laboratory experiments and four summative assessments were conducted within 68 allocated hours. Similarly, in the 10th grade, five laboratory experiments and four summative assessments were completed within the 68 allocated hours.

The summative assessments consisted of written tests designed to evaluate students' understanding of definitions, measurement units, problem-solving skills, and the application of concepts learned in class. Each test contained 7-8 items, including true-false questions, multiple-choice questions, fill-in-the-blank items, two problems with varying levels of difficulty, and tasks requiring the analysis of a problem situation or the extraction of information from a graph. The test structure was specifically designed to assess factual knowledge, procedural knowledge, and conceptual understanding. Each summative assessment was scored on a scale of 10 points, with whole numbers used for grading.

The laboratory experiments followed those outlined in the curriculum. They focused on hands-on experimentation, emphasizing the development of students' experimental and analytical skills. Each lab was divided into two parts: the first part, involving experimental work and data collection, was carried out in groups of four students, while the second part, which involved calculating indirect quantities, drawing conclusions, and completing the final report, was done individually. Laboratory work was evaluated based on the accuracy of the calculations, precision of execution, data analysis, and the conclusions drawn from the experiments.

All assessments and laboratory work were conducted during regular class periods, lasting one academic hour, and were administered under teacher supervision following standardized instructions to ensure consistency across classes.

2. 5. Intervention Program

Physics lessons in all classes were conducted using the 5E model (Bybee et al., 2006), incorporating elements of the Flipped Classroom (Bergmann & Sams, 2012) and the Early Physics Approach (Bologna et al., 2024). It is important to note that this teaching method was used throughout the entire academic year and was introduced for the first time to the participating classes. Before each physics lesson, students were assigned the task of watching a video lesson on the educatieonline.md platform, reading the relevant topic from the textbook, and answering two or three review questions. It is important to note that each chapter is structured into learning units lasting two or three hours. The first hour of each learning unit utilizes the aforementioned three methods, while the remained hours are focused on deepening conceptual understanding through problem-solving and the analysis of problem situations.

The integration of the Flipped Classroom method into traditional lessons organized according to the 5E model modifies only the first two stages. In the Engagement phase, students participate more actively in the lesson and express their opinions, as they have already been introduced to the material. In the Explanation phase, students can discuss and clarify concepts, allowing the teacher to adopt a more facilitative role in guiding class discussions. At this stage of our study, we can already assert that the application of the Flipped Classroom method increases the frequency of interactions. However, the emphasis is placed on the quality of student-teacher interactions during physics lessons. This interaction is akin to the feedback-based or interactive learning seen in other contexts: just as a priest and deacon attentively respond to each other during a liturgy, the student and teacher in a physics lesson form an indivisible harmonic oscillator that operates through three phases: Elicitation, Response, and Feedback (Wallace & Donovan, 2006). This reflects the essence of the Visible Teaching and Learning theory: on one side, the didactic goals set by the teacher are understood and embraced by the student, while on the other side, the teacher gains insight into how the student assimilates new concepts (Hattie & Yates, 2013). We place great emphasis on feedback in physics lessons—it must be continuous, immediate, and reciprocal, as feedback shapes the student's attitude toward learning (Calalb, 2021).

Throughout all five phases of the lesson, we apply the principles of the Early Physics Approach, specifically: scaffolded learning, interactive activities, integration of knowledge, and the use of multiple representations. For instance, to enhance interactivity, physics lessons incorporate demonstrative experiments from the school laboratory alongside activities on educational platforms such as phet.colorado, vascak.cz, fizichim.ro, and educatieinteractiva.md. These platforms are also utilized by students to prepare for laboratory work.

Moreover, the consistent application of the Flipped Classroom method facilitates scaffolded learning. We cannot effectively guide a student who lacks a minimum level of a priori knowledge, interest, and motivation. Additionally, using the Flipped Classroom approach allows us to gain valuable time to analyze problem situations, providing opportunities to integrate various segments of knowledge and thereby fostering coherent conceptual understanding.

Another key aspect of our approach is the application of the concept of Big Scientific Ideas (Harlen, 2010) through formative assessment, which involves posing two to three questions during the lesson. This method facilitates the assimilation of small pieces of information, aligning with Distributed Practice or interleaved learning. It is one of the most effective learning techniques because it incorporates a combination of efficient strategies: short learning sessions in which one or two new concepts are introduced, recurrent learning or periodic review of the material, and spaced learning sessions to prevent cognitive overload (Donoghue & Hattie, 2021). The effectiveness of practice testing, which relies on frequent formative assessments and immediate feedback following tests, underscores the significance of classroom interactivity and ongoing feedback (Hattie, 2016).

In conclusion, we practically combine lab work with simulations and flipped classroom elements. Indeed, according to other research, secondary school teaching would have a greater impact on conceptual understanding if a balance between experimentation and observation, contextualization, and the use of videos and simulations is achieved (Bigozzi et al., 2018).

2. 6. Data Collection and Analysis

Table 1 presents the descriptive statistics for the average marks obtained by sixth-grade students during the school year in laboratory work and summative assessments. Based on the low values of skewness, we can speak of an almost symmetric distribution of the data. However, for the overall skewness values, both for boys and girls combined, we observe a more pronounced negative skewness for both laboratory and assessment grades, meaning there is a leftward asymmetry or that the grades are shifted toward the right side of the graph—indicating that higher marks, above seven, are more prevalent.

Table 1. *Descriptive Statistics for 6th Grade*

	Lab Work			**Summative evaluation**		
	Total	G	B	Total	G	B
Valid	93	50	43	93	50	43
Median	7.000	7.000	7.000	7.200	7.250	6.800
Mean	7.110	7.342	6.840	7.003	7.312	6.644
Std Deviation	1.367	1.212	1.497	1.159	0.976	1.260
Skewness	-0.006	0.046	0.157	-0.335	0.169	-0.316
Std. Error of Skewness	0.250	0.337	0.361	0.250	0.337	0.361
Minimum	4.300	4.300	4.300	3.800	5.000	3.800
Maximum	10.000	10.000	9.800	9.600	9.600	9.200

Table 2 presents the descriptive statistics for the average marks obtained by eighth-grade students during the school year in laboratory work and summative assessments. Compared to the sixth grade, the skewness values are higher and negative for all examined cases. Therefore, the marks in the eighth grade are higher than those in the sixth grade. This is also evident from the median, mean, minimum, and maximum values for these marks.

Table 2. *Descriptive Statistics for 8th Grade*

	Lab Work			**Summative evaluation**		
	Total	G	B	Total	G	B
Valid	72	41	31	72	41	31
Missing	0	0	0	0	0	0
Median	7.900	8.000	7.800	7.500	8.000	7.300
Mean	7.775	7.980	7.503	7.557	7.883	7.126
Std Deviation	1.368	1.257	1.479	1.305	1.290	1.214
Skewness	-0.193	-0.169	-0.072	-0.103	-0.267	-0.019
Std. Error of Skewness	0.283	0.369	0.421	0.283	0.369	0.421
Minimum	5.000	5.500	5.000	5.000	5.000	5.300
Maximum	10.000	10.000	10.000	10.000	10.000	9.300

Table 3 presents the descriptive statistics for the average marks obtained by tenth-grade students during the school year in laboratory work and summative assessments. When comparing the results of tenth-grade students with those of sixth and eighth graders, we can state: the minimum values, medians, and means have increased; for laboratory work, skewness indicates an almost symmetric distribution with most marks being higher than seven; for assessments, skewness values show that the marks are distributed more uniformly—resulting in a more flattened distribution curve with a peak in the range of grades 6-8.

Thus, from Tables 1-3, we can present the results of comparing academic performance across grades:

- For laboratory work, the average mark in the eighth grade is 9.4% higher than in the sixth grade and 6.3% lower than in the tenth grade.
- For summative assessments, the average mark in the eighth grade is 8.0% higher than in the sixth grade and 2.4% higher than in the tenth grade.

- The academic quality (or the percentage of marks higher than an 8) is: 17.2% in the sixth grade, 43.06% in the eighth grade, and 33.3% in the tenth grade.

Table 3. *Descriptive Statistics for 10th Grade*

	Lab Work			Summative evaluation		
	Total	G	B	Total	G	B
Valid	30	21	9	30	21	9
Missing	0	0	0	0	0	0
Median	8.300	8.200	8.400	7.000	7.000	6.700
Mean	8.273	8.295	8.222	7.383	7.352	7.456
Std Deviation	0.972	0.873	1.231	1.141	1.074	1.353
Skewness	-0.054	-0.062	0.022	0.514	0.466	0.597
Std. Error of Skewness	0.427	0.501	0.717	0.427	0.501	0.717
Minimum	6.400	6.600	6.400	5.700	5.700	6.000
Maximum	10.000	10.000	10.000	9.500	9.500	9.500

The distribution of average marks from laboratory work throughout the academic year for grades 6th, 8th, and 10th is presented in Figure 1. As these diagrams confirm the normality of the data distribution, we can assert that it makes sense to perform a statistical analysis of the data, and the conclusions drawn will be relevant and suitable for the research objectives.

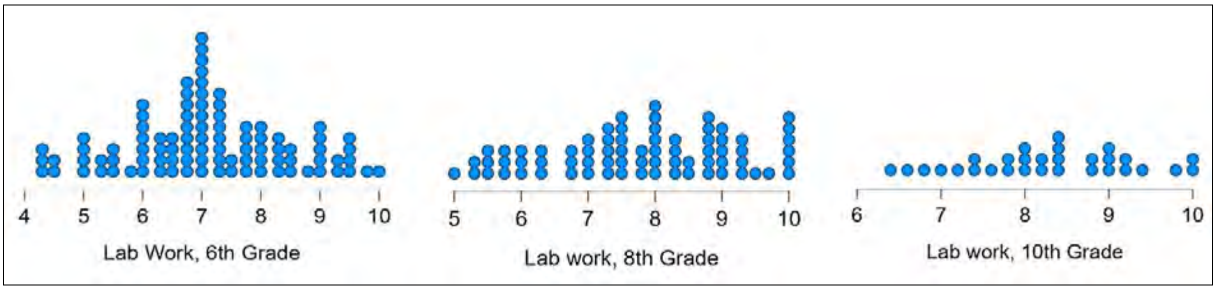

Figure 1. *Scatter plot for the average marks for laboratory work*

The distribution of average marks from summative assessments throughout the academic year for grades 6, 8, and 10 is presented in Figure 2. It is worth noting that Figures 1 and 2 confirm a more pronounced negative skewness in the summative assessments for sixth and eighth grades and a higher skewness value for the tenth grade.

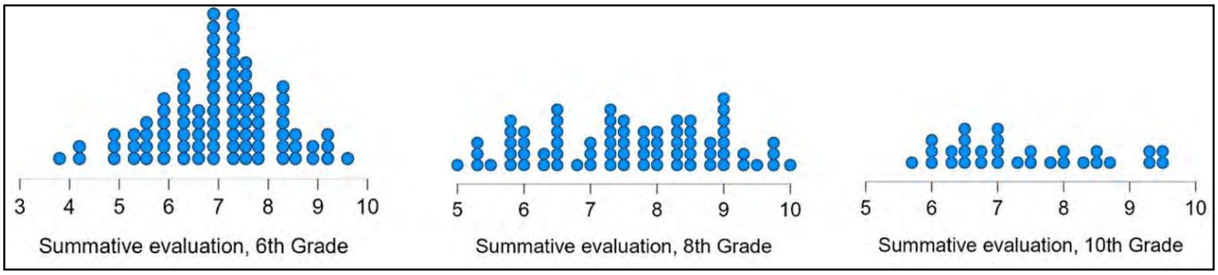

Figure 2. *Scatter plot for the average marks for summative evaluation*

In order to check H_1 and to observe how students' performance varies from one grade to another, as well as the trends throughout the year, lets analyze Table 4, which presents the results of summative assessments from the beginning of the school year, the end of the school year, and the average of all assessments throughout the year for two groups of students — those who score "ten" and "nine" and those who score "five" and "six".

Table 4. *Evolution of students' academic success throughout the year*

Grade, Nr. of students	Mark from last summative evaluation	Nr. of students	Average mark from all evaluations	Average mark from first summative evaluation	Variation in academic performance
6^{th}, 95 students	"10"	9	8,31	8,66	+15,5%
	"9"	5	7,84	8,4	+ 7,1%
	…				
	"6"	11	6,21	6,63	–10,5%
	"5"	7	5,63	5,14	– 2,8%
8^{th}, 73 students	"10"	16	8,94	8,73	+14,5%
	"9"	17	8,35	8,59	+ 4,8%
	…				
	"6"	9	6,22	6,0	0,0%
	"5"	6	5,45	6,0	– 20,0%
10^{th}, 30 students	"10"	3	9,1	9,0	+11,1%
	"9"	7	8,34	7,29	+ 23,5%
	…				
	"6"	3	6,1	5,33	+12,6%
	"5"	0			

From Table 4, it is evident that out of 95 sixth-grade students, 14 students (or 14.7%) score "ten" and "nine," while 18 students (or 18.9%) score "five" and "six." Out of 73 eighth-grade students, 33 students (or 45.2%) score "ten" and "nine," while 15 students (or 20.5%) score "five" and "six." Out of 30 tenth-grade students, 10 students (or 33.3%) score "ten" and "nine," while 3 students (or 10.0%) score "five" and "six."

Thus, we can conclude that eighth and tenth-grade students have better marks in physics compared to those in the sixth grade, who are studying physics for the first year. Alongside several factors that could explain this trend, it is worth noting that all these students have the same physics teacher who employs constructivist methods, meaning the cognitive effort of the student is prioritized.

Regarding the individual progress of students, the research results indicate that high-performing students in middle school increase their academic performance throughout the school year, while low-performing students decrease theirs. In high school, academic performance improves during the year for both high and low-performing students, but it increases approximately twice as much for high-performing students compared to low-performing students (23.5% vs. 12.6%).

In order to check H_2, the Pearson correlation coefficient was calculated between the marks obtained in laboratory work and those obtained in summative assessments for each grade, in order to determine how well laboratory performance predicts summative assessment results. Table 5 presents the results of the Pearson's r calculation and *p-values* for the sixth, eighth, and tenth grades.

Table 5. *Pearson's Correlations between Lab Work and Summative Evaluation for 6^{th}, 8^{th} and 10^{th} Grades*

	Variable		Lab Work
6^{th} grade	Summative evaluation	Pearson's r	0.747
		p-value	<0.001
8^{th} grade	Summative evaluation	Pearson's r	0.836
		p-value	<0.001
10^{th} grade	Summative evaluation	Pearson's r	0.656
		p-value	<0.001

Since the values for Pearson's r in the sixth and eighth grades are positive and greater than 0.7, we can confidently assert that there is a very strong relationship between students' performance in laboratory work and their performance in summative assessments. For the tenth grade, we have a strong correlation. Based on these Pearson correlation coefficient values, we conclude that, in general, students who achieve high marks in laboratory work tend to also achieve high marks in summative assessments. However, it is important to emphasize that while there is a strong correlation, this does not necessarily imply causation. In other words, laboratory marks do not necessarily influence summative assessment marks at the end of the chapter. We can only state that students who perform well in laboratory work tend to perform well in summative assessments.

In order to visualize the relationship between grades from laboratory work and summative assessments, we construct scatter plots (see Fig. 3). In Fig. 3, each dot represents a set of coordinates (x; y), where x is the average mark obtained by the student in laboratory work, and y is the average mark from the summative assessments. From the scatter plots, based on the slope of the correlation line, we can visually infer the presence of a strong correlation between the data sets examined. For example, the most pronounced slope is observed in the eighth grade, while the slope is more moderate in the tenth grade.

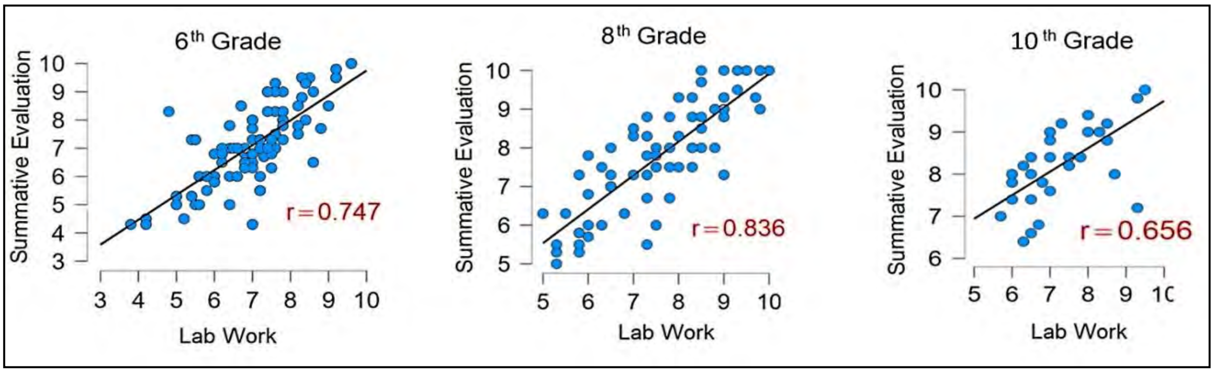

Figure 3. *Scatter plot for the correlation between summative evaluation results and lab work marks*

In order to determine the extent to which laboratory grades influence summative assessment results, we use linear regression analysis. Thus, the impact of laboratory work on summative assessments is described in Table 6.

Table 6. *Linear regression between lab work marks and summative evaluation marks*

Grade	Model	R	R^2	Adjusted R^2
6th Grade	H_0	0.000	0.000	0.000
	H_2	0.747	0.558	0.554
8th Grade	H_0	0.000	0.000	0.000
	H_2	0.836	0.698	0.694
10th Grade	H_0	0.000	0.000	0.000
	H_2	0.656	0.431	0.410

The results of the linear regression analysis show that the variability in assessment marks can be explained by laboratory marks to the extent of 55.8% in the sixth grade, 69.8% in the eighth grade, and 43.1% in the tenth grade. Therefore, based on this model, we can assert that laboratory marks are a good predictor of assessment marks. Additionally, we can confidently state that the null hypothesis regarding the absence of correlation between laboratory work and summative assessment results is not supported, and the alternative hypothesis H_2 is confirmed.

In order to check H_3 and H_4, we analyze whether there are significant differences between the performance of boys and girls in laboratory work and summative assessments. For this purpose, we use Student's t-Test for gender differences (see Table 7).

The *t-test* shows that in the sixth and eighth grades, there are significant gender differences, with girls performing better than boys in both summative assessments and laboratory work. In the tenth grade, these differences are not significant, and the negative value of t indicates that boys performed slightly better than girls on the summative assessment tests at the end of the chapters.

Table 7. *Student's t-test for gender differences*

Grade		*t*	*df*	*p*
6th Grade	Summative Evaluation	2.877	91	0.005
	Lab Work	1.789	91	0.077
8th Grade	Summative Evaluation	1.478	70	0.144
	Lab Work	2.529	70	0.014
10th Grade	Summative Evaluation	-0.223	28	0.825
	Lab Work	0.185	28	0.854

3. Discussions

Regarding H_1, we can confidently affirm that this alternative hypothesis is confirmed: There is a significant improvement in students' physics marks from the sixth grade to the tenth grade. The lower marks in the sixth grade can be attributed to several factors: physics is a new school subject for sixth-grade students; in higher grades, the impact of constructivist learning on academic success becomes apparent; students in the eighth and tenth grades are accustomed to the teacher's teaching style and familiar with the expectations and success criteria. At the same time, our result does not align with the general trend of declining success and interest in physics with age and progression from one grade to another in traditional or conventional teaching methods. However, the improvement in success in the eighth grade compared to the sixth grade qualitatively corresponds with the Visible Teaching and Learning theory by John Hattie, which suggests that within two years, an experienced teacher can increase students' academic success by at least 40%, regardless of the method applied (Hattie & Yates, 2013).

Regarding H_2, we emphasize that this alternative hypothesis is confirmed: There is a significant positive correlation between the marks obtained in laboratory work and those obtained in summative assessments in physics. This is confirmed both graphically by Figure 3, where in all three cases for sixth, eighth, and tenth grades, the theoretical curves have a significant positive slope, and analytically by the linear regression results: 55.4% of the variability in summative assessment grades in the sixth grade is explained by laboratory grades, 69.4% in the eighth grade, and 41% in the tenth grade. We note that these results should be considered qualitative, as the precision of the model depends on the sample size and the number of factors considered (in this case, only one factor was taken into account). It would be interesting to include other factors such as attitude, metacognition, cognitive effort, application of technology, or absences—as a social factor (see Figure 4, where academic success slightly decreases with an increasing number of absences). In general, this result illustrates the influence of Doing on Learning, which means it reflects the impact of students' personal effort during laboratory work on their success. Although laboratory work has a significant impact on student success, it is allocated only one-ninth of the total class hours. Therefore, we estimate that including more laboratory work (not just one per chapter) or incorporating research-based learning elements into each learning unit would increase students' academic success, deepen their conceptual understanding, and contribute to the development of students' physical science identity.

The existence and variation of significant gender differences in studying physics are shown in Tables 1-3 and Table 7. From Tables 1-3, we conclude that in laboratory work, the results for girls in the eighth and sixth grades are approximately 7% better than those for boys, and in summative assessments, they are about 10% better. In the tenth grade, the difference between boys' and girls' results is only 1%. The same conclusion is drawn from Table 7, where the *t-test* values indicate certain gender differences in the sixth and eighth grades, and the absence of differences in the tenth grade—the first year of high school in Moldova. Thus, the alternative hypothesis H_3 is confirmed for middle school grades but not for high school grades. Thus, gender differences in studying physics decrease with age and the transition from middle school to high school. The alternative hypothesis H_4 is confirmed — gender differences in studying physics diminish with age.

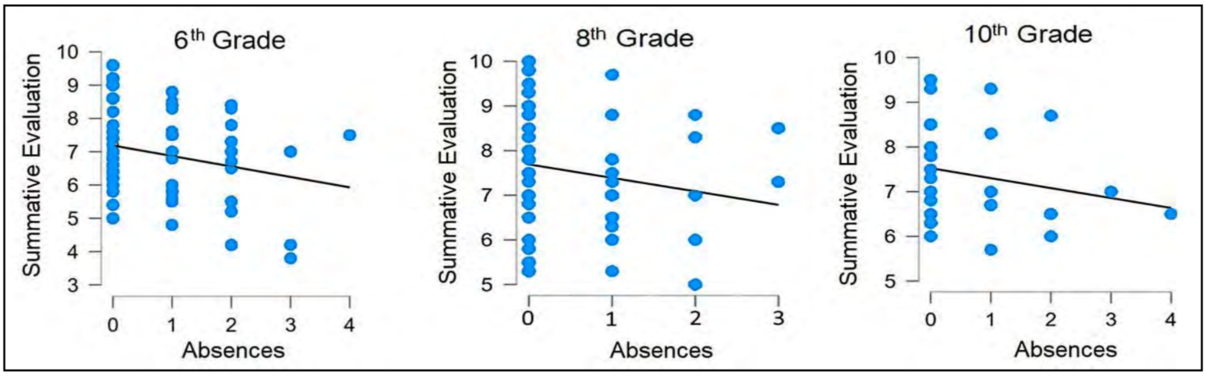

Figure 4. *Scatter plot for the correlation between summative evaluation marks and absences.*

6. Conclusions

This study applied a mix of constructivist teaching strategies such as 5E, Flipped Classroom, and Early Physics Approach, which are focused on developing students' physics identity. For example, the 5E lesson phases are based on three major inputs from the student: skill – the pre-existing knowledge and abilities to work in a laboratory; will – the attitude towards the content and the appreciation of the necessity of the task; and thrill – the motivation, goal-setting, and understanding of success criteria (Hattie & Donoghue, 2016). In addition, the Early Physics Approach aims to overcome traditional teaching issues, such as the lack of scientific skills among students, by focusing on teachers' Pedagogical Content Knowledge (PCK) and aligning with students' learning needs in the early years of physics education (Bologna et al., 2024). Finally, Flipped Classroom puts the accent on students' cognitive effort. We see physics identity strongly linked with knowledge and understanding of physics concepts. According to L.S. Vygotsky, namely the teaching which is aimed at the formation of scientific concepts creates a zone of proximal development. In other words, not all teaching develops, but only the teaching focused on the formation of scientific abilities which include (but are not limited to) the following specific actions: collecting and analysing data obtained during experiments, formulating hypotheses and theories to explain the data, testing and evaluating these hypotheses, and using specific means to represent the phenomena being studied and to communicate ideas. In fact, these are the stages of inquiry-based learning, which is cyclical and project-based. (Margolis, 2020).

Thus, as a result of our research, we can affirm that the synergy of the constructivist procedures applied to the physics lesson and laboratory work, in the long term, positively influences the academic success of students from the first year of studying physics to high school. According to other researches transition from traditional cookbook-recipe style labs to open-ended ones according to the model of ESSENCe Pedagogy (Experimental problem-solving using Staging, Scaffolding, Embedded information sources, iNstruments, and Collaboration) has a statistically significant improvement experimental problem-solving skills of students. Other effects mentioned by students are increased conceptual understanding and bridging the theory and practice (Narayanan et al., 2023).

Another important result of our research is the existence of positive significant correlation between the results of lab work and summative end-of-chapter evaluation. This correlation proves once again the influence of Doing on Learning.

Our findings show that in 6th and 8th grades girls perform better than boys both at lab works and evaluations. In high school classes these differences are flattened. In this way, according to our and other researches, at the school level, especially in the middle school classes, we still cannot talk about masculine culture of physics. Because assigned roles within group work in physics lab, which was applied by us, reduces the gender gap (Doucette & Singh, 2024). In general, the lab work in a constructivist environment is not a negative experience both for girls and boys. According to our results in high school the academic performance increased during the year for both good and poor students, but for good students about twice as much as for poor students. Also, at the level of those school students who perform in science more poorly, girls' average performance was better than boys and had smaller score variation. However, at the level of good students, boys outperformed girls – these results correspond to the ones obtained by (Chang, 2019).

Also, in high school we have obtained that boys have higher average scores on assessments and girls – lower scores – similar to other researches (Stoeckel & Roehrig, 2021). Despite expectations and stereotypes, following our results both for boys and girls, physics has lower masculinity attribution. This result corresponds to other researches (Makarova et al., 2019).

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